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TITLE: Project Support Services for the Operational Mission and Scenario Analysis for Multiple UAVs/UCAVs Control from Airborne Platforms. Phase II

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ABSTRACT: This document presents a Mission and Scenario Analysis which captures the nature of the UAV/UCAV domain within Canada. The information contained within this report will facilitate the continued development of the knowledge−base associated with two emerging technology threads: UAV/UCAV devices and Intelligent/Adaptive Interfaces (IAIs). Two scenarios were produced as a result of this exercise with the intent to provide a baseline facility for the development of an experimental landscape for the evaluation of IAI constructs. The UAV operational context was utilized primarily because of its intense, yet bounded, command and control architecture. The original scenario was developed for DRDC to provide a framework to illustrate the elements described in the mission analysis and to identify the unique mission−critical operational activities performed by the UAV MCE team on an airborne platform. Additional requirements identified by CFEC warranted the creation of a next generation mission scenario that mimics elements of the upcoming Atlantic Littoral ISR Experiment (ALIX) as well as portray potential Canadian Forces UAV capabilities. Both scenarios are based on the same type of mission (counter drug operations) composed from a similar sequence of events. The primary deviation is the employment of a family of UAVs (MALE, Tactical, and Mini UAVs) in the next generation scenario as opposed to solely a MALE UAV in the original scenario.
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Phase II

Summary Report

Completed by:

G. Youngson, K. Baker, D. Kelleher, S. Williams

G&A

GREENLEY & ASSOCIATES

PWGSC Contract No. W7711-037852/A
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On behalf of
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March 2004

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March 2004

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ABSTRACT

This document presents a Mission and Scenario Analysis which captures the nature of the UAV/UCAV domain within Canada. The information contained within this report will facilitate the continued development of the knowledge-base associated with two emerging technology threads: UAV/UCAV devices and Intelligent/Adaptive Interfaces (IAIs). Two scenarios were produced as a result of this exercise with the intent to provide a baseline facility for the development of an experimental landscape for the evaluation of IAI constructs. The UAV operational context was utilized primarily because of its intense, yet bounded, command and control architecture. The original scenario was developed for DRDC to provide a framework to illustrate the elements described in the mission analysis and to identify the unique mission-critical operational activities performed by the UAV MCE team on an airborne platform. Additional requirements identified by CFEC warranted the creation of a next generation mission scenario that mimics elements of the upcoming Atlantic Littoral ISR Experiment (ALIX) as well as portray potential Canadian Forces UAV capabilities. Both scenarios are based on the same type of mission (counter drug operations) composed from a similar sequence of events. The primary deviation is the employment of a family of UAVs (MALE, Tactical, and Mini UAVs) in the next generation scenario as opposed to solely a MALE UAV in the original scenario.

RÉSUMÉ

Le présent document renferme l'analyse d'une mission et d'un scénario cernant la nature du domaine des UAV/UCAV à l'intérieur du Canada. Les renseignements qui font partie de ce rapport faciliteront le développement continu de la base des connaissances associées à deux sujets relatifs à la technologie émergente : les UAV/UCAV et les interfaces intelligentes/adaptatives (IIA). À la suite de cet exercice, on a établi deux scénarios avec l'intention de fournir une installation de base afin de développer un contexte expérimental pour l'évaluation de concepts d'IIA. Le contexte opérationnel des UAV a été utilisé principalement à cause de son architecture de commande et de contrôle intense mais limitée. Le scénario d'origine a été élaboré pour RDDC, afin de fournir un cadre pour illustrer les éléments décrits dans l'analyse de la mission et identifier les uniques activités opérationnelles essentielles à la mission auxquelles s'adonne l'équipe MCE des UAV sur une plate-forme aéroportée. Les exigences additionnelles identifiées par le CEFC justifiaient la création d'un scénario de mission de la prochaine génération simulant les éléments de la prochaine expérience de RSR sur le littoral atlantique (ALIX) et décrivant les capacités susceptibles de posséder les UAV des Forces canadiennes. Ces deux scénarios sont basés sur le même type de mission (opérations de lutte antidrogue) et constitués d'une séquence similaire d'événements. La principale différence tient à l'utilisation d'une famille d'UAV (MALE, tactiques et miniaturisés) pour le scénario de la prochaine génération, au lieu d'un UAV MALE seulement, comme dans le scénario d'origine.

Executive Summary

This document presents a Mission and Scenario Analysis which captures the nature of the UAV/UCAV domain within Canada. This information will further the knowledge-base on two emerging technology threads: UAV/UCAV devices and Intelligent/Adaptive Interfaces (IAIs). Two scenarios produced as a result of this exercise are intended to be used as a baseline facility for experimentation, using the UAV structure as a testbed to evaluate the impact of various IAI constructs, upon operations within this domain.

The original mission scenario was developed for DRDC to provide a framework to illustrate the elements described in the mission analysis and to identify the unique mission-critical operational activities performed by the UAV MCE team on an airborne platform. Although the number of UAVs that the MCE can be expected to manage simultaneously is unknown at present, this scenario was designed to expose the airborne UAV MCE team to the maximum workload that could realistically be expected.

Additional requirements identified by the CFEC office warranted the creation of a next generation mission scenario. This scenario mimics elements of the upcoming Atlantic Littoral ISR Experiment (ALIX) as well as portray potential Canadian Forces UAV capabilities in approximately 5 years.

Both scenarios are based on the same type of mission (counter drug operations) composed from a similar sequence of events. The primary deviation is the employment of a family of UAVs (MALE, Tactical, and Mini UAVs) in the next generation scenario as opposed to solely a MALE UAV in the original scenario. Despite the discrepancies, both scenarios support the evaluation of IAI constructs upon UAV operations. To that end, they each contain time periods that may exhibit excessive operator workload due to factors such as simultaneous receipt of sensor data from multiple UAVs, dynamic re-tasking of UAVs, transfer of UAV control between agencies, and/or concurrent control of multiple UAVs.

Sommaire

Le présent document renferme l'analyse d'une mission et d'un scénario cernant la nature du domaine des UAV/UCAV à l'intérieur du Canada. Ces renseignements feront suite à la base des connaissances sur deux sujets relatifs à la technologie émergente : les UAV/UCAV et les interfaces intelligentes/adaptatives (IIA). Les deux scénarios établis à la suite de cet exercice sont censés être utilisés comme installation de base pour des expérimentations utilisant la structure d'un UAV comme banc d'essais pour l'évaluation de l'impact de différents concepts d'IIA, dans le cadre d'opérations dans ce domaine.

Le scénario d'origine de la mission a été élaboré pour RDDC, afin de fournir un cadre illustrant les éléments décrits dans l'analyse de la mission et identifiant les uniques activités opérationnelles essentielles à la mission auxquelles s'adonne l'équipe MCE des UAV sur une plate-forme aéroportée. Même si le nombre d'UAV que l'équipe MCE peut s'attendre de gérer simultanément demeure pour le moment inconnu, ce scénario a été conçu de façon à exposer l'équipe MCE des UAV à la charge de travail maximale à laquelle elle peut s'attendre de façon réaliste.

Les exigences additionnelles identifiées par le CEFC justifiaient la création d'un scénario de mission de la prochaine génération. Ce scénario simule les éléments de la prochaine expérience de RSR sur le littoral atlantique (ALIX) et décrit les capacités que pourront posséder les UAV des Forces canadiennes dans environ 5 ans.

Ces deux scénarios sont basés sur le même type de mission (opérations de lutte antidrogue) et constitués d'une séquence similaire d'événements. La principale différence tient à l'utilisation d'une famille d'UAV (MALE, tactiques et miniaturisés) pour le scénario de la prochaine génération, au lieu d'un UAV MALE seulement, comme dans le scénario d'origine. Malgré leurs différences, ces deux scénarios aident à l'évaluation des concepts d'IIA dans le cadre d'opérations d'UAV. À cette fin, ils comportent chacun des périodes de temps au cours desquelles la charge de travail peut être excessive à cause de facteurs comme la réception simultanée de données de capteurs de nombreux UAV, la réattribution dynamique des missions des UAV, le transfert du contrôle d'un UAV entre des organismes et/ou le contrôle simultané de nombreux UAV.

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1 Introduction

This document is Summary Report submitted by Greenley & Associates Incorporated as per the deliverable requirements associated with the Project Support Services for the Operational Mission and Scenario Analysis for Multiple UAVs/UCAVs Control from Airborne Platform contact (W7711-037852/A).

1.1 Background

Defence Research and Development Canada (DRDC), is responsible for the provision of germane and well-timed technologies to service the requirements of the Canadian Forces (CF). This activity requires the coordination of activities conducted by agencies within DRDC, other governments (national and international), commercial enterprises, and the academic domain. One domain that is currently being explored by DRDC is that of Uninhabited Aerial Vehicles (UAV) and Uninhabited Combat Aerial Vehicles (UCAV).

Over recent years, the concept of utilizing UAVs and UCAVs has been developed for implementation in the Canadian defence landscape. Significant inroads into the development of the technology have been completed by American, Canadian and other NATO defence interests, and the climate is opportune for the Canadian Forces to take advantage of this burgeoning domain to meet their own defence requirements.

With the conduct of Exercise Robust Ram in 2002, the CF launched the first Canadian UAV, significantly advancing the corporate understanding of the UAVs/UCAVs and the Intelligence gathering, Surveillance, and Reconnaissance (ISR) environment. DRDC, through its investigations/analyses into Command and Control modelling and simulation, are in an excellent position to leverage existing capabilities to further advance the integration of UAVs/UCAVs into the CF.

1.2 Objective

The objective of this document is to present the Mission and Scenario Analysis which captures the nature of the UAV/UCAV domain within Canada. Furthermore, this information will establish the base for additional and subsequent analyses that will facilitate UAV/UCAV concept exploration.

It is not possible to consider the objective of this short-term project without considering the goals of the long-term project with which it is associated. The mandate of the parent project is to further the corporate knowledge-base on two emerging technology threads: UAV/UCAV devices and Intelligent/Adaptive Interfaces (IAIs). The scenario produced as a result of this exercise is intended to be used as a baseline facility for experimentation, using the UAV structure as a testbed to evaluate the impact of various IAI constructs, upon operations within this domain. As such, these longer term objectives were considered during the development of the mission analysis dataset and the consequent evolution of the scenario.

1.3 This Document

This document provides the findings of the Mission and Scenario Analysis for the CF employment of a UAV/UCAV family consisting of a Medium Altitude Long Endurance (MALE)

UAV (e.g. Predator, Hummingbird), Vertical Takeoff and Landing (VTOL) Tactical UAV (VTUAV), and Mini UAV. Specifically, the report includes:

a. Introduction, including general, background, objectives of the study, scope of the report, and report structure;

b. Discussion on the process and resources utilized (incorporating information originally presented in the Investigation Summary – Progress Report #1);

c. Investigation into the current and anticipated capabilities of the simulation domain to support the development of a controlled experimentation landscape to further the corporate knowledge base on both UAV/UCAVs and IAIs (incorporating information originally presented in the Investigation Summary – Problem Report #1);

d. Description of the UAV/UCAV system to be employed within the confines of the mission scenario;

e. Mission elements describing/characterizing the operational requirements and domain; and

f. Mission scenario.

Unless otherwise specified, use of the term UAV throughout the document is analogous to UAV/UCAV.

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The following references were utilized in the creation of the summary report.

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1.5 Acronyms

AADC	Area Air Defense Commander
ACA	Airspace Control Authority
ACC	Air Combat Command
ACP	Airspace Control Plan
ACTD	Advanced Concept Technology Demonstration
ADR	Air Defence Regiment
AFB	Air Force Base
AFRL	Air Force Research Laboratory
A/G/A	Air/Ground/Air
AGL	Above Ground Level
AICC	All Intercept Control Common
ALIX	Atlantic Littoral ISR Experiment
AO	Autonomous Operations
AOO	Area Of Operation
AOR	Area Of Responsibility
AS	Able Seaman
ATC	Air Traffic Control
ATO	Air Tasking Order
ATR	Automatic Target Recognition
AUVSI	Association of Unmanned Vehicle System International
AV	Air Vehicle
BDA	Battle Damage Assessment
BLOS	Beyond Line Of Site
C2	Command and Control
CAD	Canadian Air Division
CAS	Chief of the Air Staff
CAVOK	Ceiling And Visibility OK
CD OP	Counter Drug Operation
CDL	Common Data Link
CDS	Chief of Defence Staff
CF	Canadian Forces
CFB	Canadian Forces Base

CFEC	Canadian Forces Experimentation Centre
CFLO	Canadian Forces Liaison Office
CFNAHQ	Canadian Forces Northern Area Headquarters
CINC	Commander in Chief
COCOM	Combat Command
CONOPS	Concept of Operations
CONUS	Continental United States
COS J3	Chief of Staff Joint Operations
CPF	Canadian Patrol Frigate
CPX	Command Post Exercise
CR	Close Range
CSE	Communications Security Establishment
CSIS	Canadian Security Intelligence Service
CSTAR	Combat Synthetic Training Assessment Range
CTF	Commander Task Force
DARO	Defense Airborne Reconnaissance Office
DARPA	Defense Advanced Research Projects Agency
DCDS	Deputy Chief of Defence Staff
DEMPC	Data Exploitation, Mission Planning, and Communication
DGPS	Differential Global Positioning System
DIA	Defense Intelligence Agency
DIS	Distributed Interactive Simulation
DND	Department of National Defence
DOD	Department of Defence
DRDC	Defence Research and Development Canada
EO	Electro-Optical
EURO UVS	European Unmanned Vehicle Systems Association
EW	Electronic Warfare
FAS	Federation of American Scientists
FDE	Force Development Evaluation
FISHPAT	Fisheries surveillance Patrol
FL	Flight Level
FOV	Field Of View
FPS	Force Planning Scenarios

FTU	Force Training Unit
GATR	Ground Air Transmit Receive
GCS	Ground Control Station
GDC	General Dynamics Canada
GDT	Ground Data Terminal
HALE	High Altitude Long Endurance
HMCS	Her Majesty's Canadian Ship
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
IAI	Intelligent Adaptive Interfaces
ID	Identification
IG	Image Generator
Intsum	Intelligence Summary
IPB	Intelligence Preparation of the Battlefield
IR	Infrared
ISAF	International Security Assistance Force
ISR	Intelligence gathering, Surveillance and Reconnaissance
ISTAR	Intelligence, Surveillance, Target Acquisition, and Reconnaissance
JCS	Joint Chief of Staff
JDISS	Joint Deployable Intelligence Support System
JFACC	Joint Force Air Command Component
JFC	Joint Force Commander
JSTARS	Joint Surveillance and Target Attack Radar System
JTF	Joint Task Force
JWICS	Joint Worldwide Intelligence Communications System
KIAS	Knots Indicated Air Speed
KMNB	Kabul Multi-National Brigade
KTS	Knots (1 nautical mile per hour)
LADP	Low Altitude Deep Penetration
LALE	Low Altitude Long Endurance
LANTFLT	Atlantic Fleet
LFA	Land Force Area
LOCAAS	Low Cost Autonomous Attack System
LOS	Line Of Sight
LRE	Launch and Recovery Element

LRPA	Long Range Patrol Aircraft
LWIR	Long Wave IR
MAC-A	Maritime Air Commander Atlantic
MALE	Medium Altitude Long Range
MARLANT	Maritime Forces Atlantic
MARPAC	Maritime Forces Pacific
MCDV	Maritime Coastal Defense Vessel
MCE	Mission Control Element
MMA	Multi-Mission Maritime Aircraft
MND	Minister of National Defence
MOB	Main Operating Base
MOU	Memorandum Of Understanding
MR	Medium Range
MRE	Medium Range Endurance
MTI	Moving Target Indicator
MTS	Multi-Spectral Targeting System
MUSE	Multiple UAV Simulation Environment
MV	Motor Vessel
NASO	Non-Acoustic Sensor Operator
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, Chemical
NCA	National Command Authority
NCM	Non Commissioned Member
NDHQ	National Defence Headquarters
NGO	Non-Government Organization
NLE	Naval Liaison Element
Nm	nautical mile
NORAD	North American Aerospace Defence Command
NRT	Near-Real-Time
NSA	National Security Agency
OCW	Operator Control Workstation
OGD	Other Government Departments
OPCOM	Operational Command
OPCON	Operational Control

ORO	Operations Room Officer
OTC	Officer in Tactical Command
PLIX	Pacific Littoral ISR Experiment
PO	Petty Officer
PPO	Pilot and Payload Operator
PPSL	Predator Primary Satellite Link
RCMP	Royal Canadian Mounted Police
RMP	Recognized Maritime Picture
ROD	Reconnaissance Operations Division
ROE	Rules Of Engagement
RS	Reconnaissance Squadron
RTB	Return To Base
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communication
SDB	Small Diameter Bomb
SEAD	Suppression of Enemy Air Defences
SERT	Special Emergency Response Team
SIF/IFF	Selective Identification Feature/Identification Friend-or-Foe
SIOP	Single Integrated Operational Plan
SITREP	Situation Report
SME	Subject Matter Expert
SOI	Ship Of Interest
SPIN	Special Instructions
SR	Short Range
SRO	Sensitive Reconnaissance Operations
SWC	Sensor Weapons Controller
TACNAV	Tactical Navigator
TACON	Tactical Control
TCS	Tactical Control System
TEG	Test and Evaluation Group
TESAR	Tactical Endurance Synthetic Aperture Radar
TFCLANT	Task Force Commander Atlantic
TOCA	Transfer of Command Authority
TOI	Target Of Interest

TSCS	Transportable Satellite Communications System
TTP	Technique, Tactics and Procedures
TUAV	Tactical Uninhabited Aerial Vehicle
UAV	Uninhabited Aerial Vehicle
UAVS	UAV Systems Association
UCAR	Unmanned Combat Armed Rotorcraft
UCARE	UAVs: Concerted Actions for Regulations
UCAV	Uninhabited Combat Aerial Vehicle
UHF	Ultra High Frequency
UN	United Nations
UNSCR	UN Security Council Resolution
USACOM	United States Atlantic Command
USAF	United States Air Force
USCG	United States Coast Guard
USSTRATCOM	United States Strategic Command
UV	Ultraviolet
VRSG	Virtual Reality Scene Generation
VTOL	Vertical Takeoff and Landing
VTUAV	VTOL Tactical Uninhabited Aerial Vehicle

2 Process and Resources Utilized

This section outlines the general process as well as resources used during the data collection phase, which in turn culminated into the generation of the UAV mission scenario. The data collection phase was originally explained in Investigation Summary – Progress Report #1 and has been re-stated in this report for completeness.

2.1 Data Collection

A list of personnel/agencies was developed and presented to the Scientific Authority during the initial stages of this project. Depending on factors such as availability, content, area of expertise, etc, this list was reduced to accommodate the specific requirements of this project and the time available for the data collection exercise. Once this list was generated, the process for data collection was initiated.

A number of interviews were conducted with the relevant personnel/agencies to provide appropriate focus to the Canadian UAV/UCAV domain. In addition an extensive search was conducted of the open source (primarily Internet based) and "grey" literature to determine the nature of UAV development, experimentation, and simulation in the Canadian and International context.

The objective of the interviews and literature search was to:

a. identify the concept of operations for UAVs in the CF landscape;

b. characterize the command and control elements for UAVs; and

c. evaluate the state of the general simulation domain with specific focus on UAVs to determine its ability to support the experimental requirements of the Scientific Authority.

2.2 Interviews

2.2.1 Canadian Forces Experimental Centre

To gain direction into the UAV scenario development for this study as well as a better understanding of the Canadian UAV involvement, a series of interviews were conducted with Dr. P. Farrell and Maj M. Regush of the Canadian Forces Experimentation Centre (CFEC). The primary product of this exercise was the characterization of the UAV domain within the CF and the identification of specific scenario elements including high-level mission concepts, anticipated UAV crewmember configurations, cooperating agencies, and mission assumptions and constraints.

Discussions were also conducted with LCol Stephen Newton. The objective of this discussion was to determine the extent to which the scenario generated in support of this project could be used to satisfy current operational requirements as well as support future UAV exercises (e.g. Atlantic Littoral ISR Experiment (ALIX)). The initial discussion with LCol Newton spawned further discussions with Dr. Farrell and Maj Regush as to how elements of the ALIX exercise could be captured within the scenario being developed. It became apparent that both programs, DRDC-Toronto's experimental plan and ALIX would be advantaged by coupling the scenario to some extent. If specific experiments were based on scenario elements that could be

replicated during ALIX, the baseline dataset for the simulation domain could be validated against the operational domain.

2.2.2 UAV Research Test Bed – DRDC Ottawa

As a means to further understand the state of UAV simulation, the UAV Research Test Bed under the supervision of Dr. Paul Hubbard was visited. The UAV Research Test Bed is a synthetic environment developed from off-the-shelf hardware and software.

Figure 1: CAE's Reconfigurable Control Station

The UAV Research Test Bed system resident at DRDC-Ottawa was developed by CAE. The Reconfigurable Vehicle Control Station (RVCS), as indicated in Figure 1, is an integrated product, which combines a vehicle operator station with a synthetic environment to support UAV (unmanned or uninhabited aerial vehicle) research, training and operations.

2.2.3 AEgis Simulation

A review of the modelling and simulation landscape did not yield a significant number of commercially available UAV-specific simulation devices. AEgis Simulation has established a turn-key solution for a UAV simulation device, typical of the architecture of the systems. It is PC-based, High Level Architecture (HLA) capable and reconfigurable. The device elements are integrated into a notional workstation, as indicated in Figure 2, for an increased operational sense during use. It presents flight control, system management, sensor control and data capture elements in a multi-screen facility with a control interface based on traditional throttle, stick, rudder conventions extended with a touch-screen interface to the sensor/system control requirements.

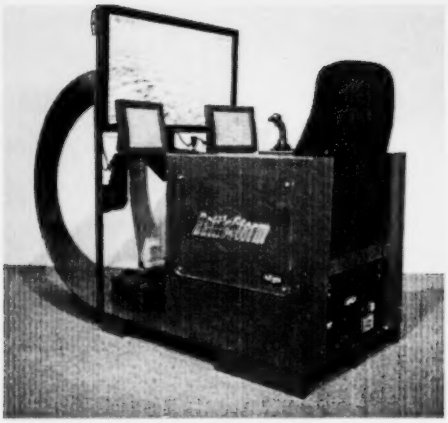

Figure 2: AEgis UAV Simulation Device

2.2.4 Directorate Science and Technology/Air

Prior to this study, CMC Electronics conducted a study [Reference 1] for the Directorate Science and Technology/Air (DST/A) on a concept of operations for controlling UAVs/UCAVs from an airborne platform. An interview with Mr. M. Roy from DSTA-4 was conducted to address any subsequent work stemming from this initial study. Although no additional work has been performed in direct support of the CMC study, Mr. Roy provided information regarding the current UAV thrusts supported by DST/A.

2.2.5 General Dynamics Canada

General Dynamics Canada (GDC) is currently developing a mini-UAV (the Grasshopper project) as well as evolving the design of a micro-UAV, in support of anticipated CF battalion-level (or below) operations. The program manager, Mr. W. Cuthbertson, was interviewed to gain insight into the product, both from a technical perspective (e.g. design decisions and constraints) as well as operational (e.g. proposed concept of operations for mini-UAVs).

An additional benefit to our discussion was gained as insight into the level of automation that has been currently implemented in the Grasshopper and future systems being developed by GDC. The basic premise is that there is a high degree of autonomy built into the flight control systems within the device, i.e. there is no requirement for the mini-UAV to be continually manned by a flight control operator. This is only possible because the operational environment for the device is so tightly restricted (i.e. low level, minimal footprint) that the traditional concerns regarding flight control do not apply.

2.3 Typical UAV Simulation Device Characteristics

The devices discussed in Sections 2.2.2 and 2.2.3 are representative of the state-of-the-art for low- to medium-fidelity UAV Simulation Devices. Table 1 captures the high-level characteristics of both the CAE and AEgis devices to facilitate the development of an understanding of the available technology.

Table 1: UAV Simulation Device Characteristics

Issue	AEgis UAV Device	CAE UAV Device
Operating System (Windows, Unix, VMS, etc)	• Windows 2000, NT, XP.	• Windows 2000 and Linux 7.3
Hardware Architecture (PC, SGI, workstation, etc)	• PC. One PC for each of three visual channels and one for the Battlestorm framework.	• PC-based, distributing processing using five PCs, supporting the Medallion IG (one channel per PC) • Off the shelf PCs
COTS Components (What is available off-the-shelf vice proprietary equipment)	• All COTS components with the exception of the UAV shell that the UAV hardware sits in.	• All COTS components with the exception of the Sensor post-processing card (proprietary) • Currently developing COTS toolset to replace the existing proprietary card set.
Scalability (How easy is it to grow this to extend the capability)	• Yes, additional PCs can be easily integrated into the architecture. • Users can also create their own modules and custom simulations.	• Yes, additional capability can be integrated into the device either through HLA protocol or STRIVE (weather server, terrain server, information services, etc)
SAF (FLAMES, OneSAF, MODSAF, STAGE STRIVE, etc)	• OneSAF, MODSAF, JSAF • Currently integrating into FLAMES and STAGE. • Can be made to integrate into any other SAF, such as STRIVE, if required.	• STRIVE
External Scene Software/Hardware (Projectors, software, scene facilities, etc)	• MetaVR VRSG and OpenFlight • uses any external scene hardware such as projectors, headsets, plasma displays etc. • models are standard model formats and with the capability of conversion of alternate formats	• Proprietary database tools • can accept OpenFlight, TerraPage, DTED, DFAD source data • Medallion IG, using COTS cards with proprietary graphics drivers
Control/Display Devices (Touch screens, joysticks, trackballs, commercially available, build-to-specification, etc)	• Can accommodate any device that can integrate with a PC using serial, parallel, USB ports • Examples of control devices include COTS game joysticks through to actual flight hardware, trackballs, touch screens, buttons, knobs, switches, analogue dials	• Joystick interface for manually controlling Computer Generated Forces • Joystick interface for the payload operator position • Everything else is keyboard controlled, traditional displays • Can be modified to incorporate other PC-based control and display devices

Table 1: UAV Simulation Device Characteristics

Issue	AEgis UAV Device	CAE UAV Device
Reconfigurability (How easy is it to re-use these tools to support the development of other simulation devices.)	• BattleStorm ships with a number of different types of vehicles that come with the standard package, ranging from attack helicopters to armoured vehicles • The input and output devices are simply selected in the Battlestorm configuration screen. • The device can be modified from the UAV to a helicopter to a main battle tank in very little time (less than five minutes). • Users can create their own modules and custom simulations, as required.	• Reconfigurable, within the bounds of the UAV domain • Any reconfiguration beyond these bounds requires additional discussions with CAE.

2.4 Literature Search and Review

In conjunction with the aforementioned interviews, an extensive search was conducted of existing open source (primarily Internet based) and grey literature to determine the nature of UAV development, experimentation, and simulation. The most relevant sources are listed below.

a. Research Facilities

1) Federation of American Scientists (FAS) – www.fas.org/irp/program/collect/uav.htm

2) Defense Airborne Reconnaissance Office (DARO) – www.fas.org/irp/agency/daro/index.html

3) National Aeronautics and Space Administration (NASA) – www.nasa.gov/home/index.html

4) Defense Advanced Research Projects Agency (DARPA) - www.darpa.mil/ucav/

5) Naval Unmanned Aerial Vehicles – uav.navair.navy.mil/home2.htm

6) Edwards Air Force Base – www.edwards.af.mil/history/index.html

7) Nellis Air Force Base – www.nellis.af.mil/awfc.htm

8) Physical Science Laboratory – www.psl.nmsu.edu/uav/

9) Global Security – www.globalsecurity.org/intell/systems/collection.htm

b. UAV forums

1) European Unmanned Vehicle Systems Association (EURO UVS) – www.euro-uvs.org

2) UAVs: Concerted Actions for Regulations (UCARE) – www.ucare-network.org/affiche.php

3) Association of Unmanned Vehicle System International (AUVSI) – www.auvsi.org

4) UAV Forum – www.uavforum.com/index.shtml

5) UVS Canada – www.uvscanada.org (joined Internet virtual community)

6) UAVNet – www.uavnet.com

7) UAV Systems Association (UAVS) – www.uavs.org

8) Shephard's UVOnline.com – www.uvonline.com

c. Military news sources

1) Jane's – www.janes.com

2) Military.com – www.military.com

3) Army magazine – www.ausa.org/www/greenbook.nsf

4) Armed Forces Journal – http://www.afji.com/AFJI/index.html

5) Global-Defence.com – www.global-defence.com/2003/index.html

d. UAV Modelling and Simulation

1) UCAV Simulation Lab – www.darpa.mil/ucav/index.htm

2) Meta VR- UAV Simulators – www.metavr.com/casestudies/TUAV.html

3) Modeling and Simulation Employed in the Predator Unmanned Aerial Vehicle Program – www.fas.org/irp/agency/daro/product/predms.htm

e. Potential/Additional Sites to be Investigated:

1) Pioneer UAV Net Recovery Simulator

2) Army CERL Virtual Environments Group

3) Advanced Simulation And Software Engineering Technology

4) SMC Modeling And Simulation Reading Room

In general, the documentation available through the DWAN, the open source and academic environments tended to be content poor in regards to the requirements of this program, requiring significant review to extract sufficient information to advance this analysis. As a consequence, data collection and mission analysis phases will continue to rely heavily on Domain Expertise as made available through DRDC and the commercial domain.

2.5 Mission Scenario Development

As a result of the team's review of available documentation in concert with information gleaned from the interviews conducted it was determined that a domestic operation, in particular the conduct of a Fishery Patrol (FISHPAT) followed by a Counter-Drug Operation (CD OP) would be developed. In turn, this would best satisfy the object of this contract; specifically the conduct of a Mission and Scenario Analysis that will establish the base for additional and subsequent analyses that will facilitate IAI concept exploration.

The FISHPAT/CD OP is an intelligence gathering, surveillance and reconnaissance mission conducted in a domestic environment. The interview process confirms that this scenario would be a realistic peacetime tasking that the Canadian Forces could receive. As an additional benefit, it would support the conduct of future UAV exercises, most notably ALIX.

The scenario will embrace all the elements required to exercise command and control from an airborne platform and will include all of the basic mission elements identified by CMC Electronics in their report on the Concept of Control of UAVs and UCAVs from Airborne Platforms [Reference 1]. The scenario will exercise the handover of UAVs from one Mission Control Element (MCE) to another during the conduct of the CD OP portion of the mission as well as during the transit to and from the Area of Operation (AOO). In addition to handovers during the CD OP, the scenario will encompass a re-tasking phase (e.g. from FISHPAT to CD OP) as well as provide the opportunity to exercise various levels of autonomy within the experimental program.

The scenario will involve the use of a family of UAVs including a MALE, VTUAV, and Mini. At present it is anticipated that there will be a maximum of four operators required in each MCE: UAV pilot, 2 payload operators, and a mission commander. This set is necessary for operating the MALE UAV during the conduct of the mission, whereas the VTUAV and Mini may employ a subset of these individuals.

The constituent elements of the scenario have been 'sketched' out through discussions with the pool of domain experts to the extent that it is possible to determine the degree of satisfaction of the primary objectives of this project. Consensus indicates that the variety of components within the target scenario domain will provide for a rich and diverse domain for analysis. That being said, the details of the individual components will need additional support from the operational community, historical documents, and domain expert pool.

3 Status of Existing and Anticipated UAV Simulation

3.1 General

Present day simulators may be highly advanced depending upon the system budget and anticipated use. Many UAV simulators are run from desk-top PCs or are incorporated into flight simulators already in use. Expected technology changes occurring in the next two years are not anticipated to generate compatibility issues between the new and old software/hardware, provided the simulator is built with the latest technology and capability. Changes can be made to system components to ensure the simulator performs with technology advances, for example, LCD displays can be changed out to plasma screens and upgrades in bandwidth should also be supportable. Further, many simulators use High Level Architecture to allow for communication between geographically distributed simulators connected through a network to the same virtual world. Again, provided a simulator is built today with this capability, it should not be made redundant within two years.

At the highest levels, modelling and simulation are being used to develop assessments of alternative force mixes of manned and unmanned reconnaissance systems, including Predator. At the next level, modelling and simulation are being used to support Predator participation in operational exercises. In these exercises, "virtual" Predators are flown by operational users because the limited quantities of real hardware assets are unavailable and because modelling and simulation yields substantive insights at considerably lower cost than operating the real assets. These exercises have contributed significantly to the development of the Concepts of Operations (CONOPS) for Predator and to an increase in the user knowledge base about the employment of UAVs in general. For instance, in FY96 Predator was modelled in the Multiple Unmanned Aerial Vehicle Simulation Environment (MUSE), which was used in a Republic of Korea/US Combined Forces and US Forces, Korea exercise called Ulchi Focus Lens 96. The MUSE was combined with an improved Joint Surveillance and Target Attack Radar System (JSTARS) simulation to provide a representation of real-time capabilities at selected theater, corps, and division level command and control headquarters. The simulations also demonstrated the tremendous challenge facing operational staff in synchronizing real-time imagery assets with battlefield operations. The US Army's III Corps has also used MUSE to do predictive simulations of Predator for its Corps-level Command Post Exercise (CPX) to test new CONOPS prior to live exercises in the field. MUSE was employed in February 1997 during III Corps UAV exercise ramp-up in preparation for the Force XXI's Advanced Warfighting Exercise.

An important consideration remains: the simulator control station will be more advanced than the field technology, therefore, future compatibility and enhancements will likely be affected by advances in field technology and equipment. Advancements in field technology including UAV camera resolution, infrared capability, and radar sensitivity will affect the simulator quality depending upon whether raw field data is injected into the simulator. Field data may be injected into the simulator completely raw, partially simulated, or fully simulated. Again, this decision is dependent upon considerations such as budget, time, and anticipated use.

UAV simulators will be able to test IAIs in the next two years to the same degree as other simulators currently in use, considering many UAV simulators are incorporated into other existing simulators or use similar technology platforms. Adaptive interfaces are capable of maintaining databases of frequently used commands and typical formatting preferences. Provided research into the frequently used commands for UAVs is conducted, and compatible technology is used, the UAV simulator will be able to support an Intelligent Adaptive Interface command suite.

3.2 Results of Open Source Literature Search

The following section outlines a portion of the modelling and simulation efforts as identified by a review of the existing open source literature.

3.2.1 Combat Synthetic Training Assessment Range

www.gd-decisionsystems.com/cstar/main.html

The Combat Synthetic Training Assessment Range (CSTAR) trainer is a system incorporating intelligence information, radar information and UAV video and telemetry into a common simulator. CSTAR takes the player information from 2000 soldiers, tanks and helicopters on a 65 km by 65 km training range and combines it with an additional 8000 simulated players extending the battlefield to 10,000 players on a 200 km by 200 km area. The data from the 10,000 live and simulated players is fed into 3 sensor models:

a. The FIRESTORM SIGINT model which simulates a number of intelligence systems (Intelligence information).

b. The JSASS Joint STARS Moving Target Indicator (MTI) model which simulates the radar on Joint STARS E-8 aircraft (Surveillance information).

c. Multiple Unified Synthetic Environment UAV which generates realistic UAV video and telemetry (Reconnaissance information).

These systems are combined in a simulator used for training purposes.

3.2.2 S2Focus Simulation Technology

www.gd-decisionsystems.com/s2focus/main.html

S2Focus is a Windows® based suite of distributed simulation tools that support exercise analysis and monitoring as well as simulation development. This system is specifically designed for HLA with support for Distributed Interactive Simulation (DIS) interoperability. S2Focus is the only all-inclusive HLA commercial off-the-shelf exercise management tool on the market. The system operates on standard Windows 2000® personal computer (800 MHz processor recommended).

3.2.3 Modeling and Simulation Employed in the Predator UAV Program

www.fas.org/irp/agency/daro/product/predms.htm

The Predator air vehicle carries both electro-optical/infrared (EO/IR) and synthetic aperture radar (SAR) sensors. A Ku-band satellite communications (SATCOM) link enables Predator to acquire imagery beyond line-of-sight and disseminate it world-wide.

Modeling and simulation are being used to support Predator participation in operational exercises. In these exercises, "virtual" Predators are flown by operational users in order to significantly contribute to the development of the CONOPS for Predator and to increase the user knowledge base about the employment of UAVs in general.

In FY96 Predator was modeled in MUSE. MUSE was combined with an improved JSTARS simulation to provide a representation of real-time capabilities at selected theater, corps, and division level command and control headquarters.

3.2.4 UCAV Overview

www.darpa.mil/ucav/index.htm

The UCAV System Integration Lab is a combination high fidelity, diverse participant simulation, and provides the ability to demonstrate up to 20 UCAVs operating in a realistic mission environment or to support system software verification and team training. The UCAV system simulation employs a Boeing developed High Fidelity Environment Model as its core and uses the Boeing Integrated Technology Development.

3.2.5 Meta VR for TUAV Embedded Visual System Trainer

www.metavr.com/casestudies/TUAV.html

This company manufactures VR simulators for UAVs. One product they manufacture is the Virtual Reality Scene Generation (VRSG)™ system, which is a real-time 3D computer image generator (IG) that enables the operator to visualize geographically expansive and detailed virtual worlds on PCs. VRSG provides real-time, single- or multiple-channel visualization of virtual environments, dynamic moving models, and special effects, using Microsoft DirectX commercial standards.

Meta also produces The Multiple Unified Simulation Environment (MUSE) simulation which has evolved into a general intelligence collection platform simulation for airborne collection systems with EO, IR, and SAR payloads. The MetaVR MUSE VRSG system was developed to provide the visualization system component for MUSE that generates synthetic payload scene video and/or imagery of the 3D battlefield with simulated target entities. This video and imagery is then fed to a tactical or generic UAV/intelligence platform control station where operators perform air vehicle and payload control functions, and an air vehicle and data-link simulation.

4 Mission Analysis

4.1 General

Mission analysis techniques should be used at the outset of the human engineering analyses during the concept development phase. This analysis is an essential precursor to all other human engineering analyses. This dataset should be continually updated during the project definition phase to reflect changes in the domain or to reflect system information that is more current in an evolving landscape, in time to influence the implementation contract.

This Mission/Scenario Analysis was conducted to provide information that defines what the intended system must do, and the environment and circumstances in which it must be done. The information culminates in a detailed dataset including narrative mission descriptions, graphic mission profiles and scenarios which may be easily used as a starting point to derive the functional requirements of the system.

Mission analysis forms the core of information to which the complete human factors engineering/modelling and simulation effort will be anchored. The mission analysis is based on information provided by a number of sources, including doctrinal documents, standard operating procedures, Techniques, Tactics and Procedures (TTP) manuals, and subject matter experts (SMEs). The SMEs comprise individuals from the operational community to which the proposed system is directed who understand, in whole or in part, the environment within which the system will be operated. The development of mission descriptions, mission profiles and operational scenarios for the purposes of this project will be derived from work conducted to date to establish the operational requirements for the anticipated UAV/UCAV systems.

Primary resources for this development exercise were the domain experts resident on the Greenley & Associates team, with support from the SME pool as made available by the Technical/Scientific Authority. The resultant descriptions and scenarios were then be subjected to a thorough review by the Scientific Authority and the operational community as provided by Department of National Defence (DND).

The development of mission descriptions, profiles and scenarios which accurately reflect the intended use of the system, as seen through the eyes of the personnel who will operate the system, is essential to the successful completion of the preliminary analysis phase of the long term project. All succeeding preliminary analysis tasks are based on this mission analysis, and this is only valid if there is sufficient participation from the operational community.

The overall objective of the mission analysis was to identify the UAV/UCAV performance requirements essential to the successful completion of its mission. Specific objectives of the analysis are to provide:

a. the description of the assumed characteristics and capabilities for the UAV/UCAV;

b. the primary and secondary roles for the UAV/UCAV;

c. the missions and mission objectives associated with these roles. In so far as the objectives to be met by the UAV/UCAV systems operating in conjunction with other systems (such as cooperating agencies) not within the scope of the contract, the following was also described:

   1) the overall objectives to be met through combined operation of systems,

   2) the sub-objectives to be met by the UAV/UCAV system being developed, and

   3) interactions required between systems to meet these objectives;

d. each distinct event in the mission from the point at which operator interaction with the UAV/UCAV commences until this interaction terminates. The analysis is sufficiently detailed to permit identification of the major mission phases, the major system functions, the timescale of activities, and the external events which influence the activities of the UAV/UCAV system;

e. where multiple missions were to be performed by the system, each was examined. These independent missions were reduced to one "composite" mission which identifies all of the unique mission activities but avoids repetition of common activities. Use of a composite mission scenario can substantially reduce the effort for the remaining preliminary analysis tasks, while ensuring that each unique event is examined in detail; and

f. factors influencing the conduct of the mission were catalogued, including climate, mission time constraints, weather, enemy threat, and presence or absence of cooperating units as required.

4.2 CF Roles, Missions and Scenarios

As a starting point for deriving a UAV mission scenario representative of realistic CF employment of the asset, existing documentation pertaining to the Canadian Forces' roles, missions and scenarios were reviewed. First, the CF roles are described as a means to identify the boundaries for CF participation in national and international incidents. Next, three mission types for the CF are characterized. Finally, the CF Force Planning Scenarios (FPS) were reviewed to illustrate the building blocks that were adapted and expanded to create the UAV mission scenario.

4.2.1 CF Roles

The 1994 White Paper on Defence [Reference 2] outlines the strategic-level roles that have been identified for the CF with the intention of providing clear direction for the CF. The remainder of this subsection provides a brief overview of each role assigned to the CF.

4.2.1.1 Protection of Canada

The following objectives are related to the defence of Canada (and Canadians) and the protection of Canadian sovereignty:

a. **Aid of the Civil Power.** Provinces can call upon the CF to maintain and/or restore law and order when it is beyond the power of civil authorities to do so. The CF role is not to replace the civil authorities, but to them in re-establishing law and order.

b. **Providing Peacetime Surveillance and Control.** Even when there is no direct military threat to Canada, the CF must ensure effective control over Canadian territory, airspace, and maritime approaches. Maintaining the capability to field a presence wherever Canada maintains sovereign jurisdiction signals that Canadians will not have their sovereignty compromised.

c. **Securing Canadian Borders against Illegal Activities.** It is the role of the CF to maintain the capability to satisfy cooperative agreements in support of other government departments. This includes aiding the Solicitor General/RCMP in countering activities such as the illegal trade in narcotics and other contraband substances and the smuggling of illegal immigrants into Canada.

d. **Fisheries Protection.** The CF devotes a significant number of flying hours and ship days to fishery patrols in order to protect Canada's fisheries from illegal and highly damaging exploitation.

e. **Disaster Relief.** The CF plays a key role in responding to natural and man-made disasters such as earthquakes, floods, and fires.

f. **Search and Rescue.** The CF contributes to the maintenance and operation of Canada's search and rescue capability. Specifically, the CF is responsible for the air search and rescue capabilities as well as providing significant resources (e.g. manpower, Command and Control (C2) facilities) to assist local authorities in land search and rescue operations (e.g. aircraft crashes or searches for lost persons).

4.2.1.2 Canada-United States Defence Cooperation

The Canadian Forces are committed to cooperating with the United States in the defence of North America. This cooperation, which is defined by various bilateral arrangements and agreements, involves the use of land, sea, and air elements.

4.2.1.3 Contribution to International Security

Finally, there are a number of objectives related to the maintenance of international security for which the Canadian government is willing to commit maritime, land, and air forces, including those set out below:

a. **Preventive Deployment of Forces.** The CF maintains the capability to deploy forces to an area of imminent dispute prior to the outbreak of conflict. The objective is to defuse tension, enhance confidence, and prevent minor incidents from escalating inadvertently to full-scale hostilities.

b. **Peacekeeping and Observer Missions.** These missions characterize the more conventional peacekeeping roles associated with the CF. Impartial CF forces are positioned between parties to a ceasefire, and monitor agreements during the course of negotiations intended to lead to a political solution.

c. **Enforcing the Will of the International Community and Defending Allies.** The most ambitious operations in recent years have used armed force, under multilateral authorization to enforce the will of the international community. These operations include enforcing economic sanctions or arms embargoes, using armed forces to secure conditions for the delivery of aid, securing 'no-fly zones', and protecting civilian populations and refugees in safe areas.

d. **Post-conflict Peacebuilding.** The rehabilitation of areas that have suffered from armed conflict presents an opportunity where the training, skills, and equipment of the CF can make an important contribution.

e. **Measures to Enhance Stability and Build Confidence.** Arms control and measures to build confidence represent an important way to prevent or limit conflict and foster stable relations between states. The CF provides valuable expertise for inspecting and verifying compliance with these arrangements.

f. **Participate in Multilateral Operations.** In addition to the multilateral operations previously discussed, the CF must be capable of meeting commitments such as North Atlantic Treaty Organization (NATO) Collective Defence, Peacetime Commitments to NATO, and International Humanitarian Assistance and Disaster Relief.

4.2.2 CF Missions

Based on the CF roles defined in the 1994 White Paper on Defence, three basic kinds of CF "mission" or "operation" can be characterized:

a. **Domestic Operations.** Domestic operations include all peacetime operations conducted within Canadian territory, airspace, and maritime approaches. The CF has been involved in a number of domestic operations in the last ten years such as the Manitoba flood and the ice storm in eastern Ontario and Quebec.

b. **Peace Support Operations.** Peace support operations include those operations conducted outside Canada under a United Nations (UN) or coalition banner. Typically, the mission mandate is provided by a UN Security Council Resolution (UNSCR). Peace support operations may be of low intensity (peace "building"), medium intensity (peace "keeping"), or high intensity (peace "enforcement"). The extent to which the use of force is authorized is the key yardstick of peace support mission intensity.

c. **War-fighting Operations.** War-fighting operations refer to offensive and defensive combat operations conducted inside or outside Canada, usually in concert with allies, against a modern well-equipped enemy.

4.2.3 CF Force Planning Scenarios

The CF Force Planning Scenarios [Reference 3] provide realistic situations that could be encountered for each type of generic missions the CF could be called upon to perform. Specifically, the scenarios outline a planned series of real or imaginary events including details pertaining to the various scenes and situations as well as the cast of characters. The scenarios are based upon current defence policy and are set at the strategic level.

These credible and realistic scenarios offer a framework within which long-term departmental force planning and analyses can be conducted by DND and the CF. Within the confinements of the UAV mission scenario, the scenarios provide a starting point for rationalizing future UAV requirements and force structure. From a practical standpoint, the scenarios offer a skeleton for constructing a UAV mission scenario since each one has been designed to be extendable and adaptable to developing "vignettes" at the operational and tactical levels.

The 11 force planning scenarios are listed below with a brief description of a plausible situation for each one.

a. **Search and rescue in Canada.** A major airliner has been forced down in a remote part of Northern Canada and there are survivors.

b. **Disaster relief in Canada.** An earthquake has occurred on the west coast resulting in major devastation—fires have broken out, buildings and highways are damaged, and basic utilities disrupted. The magnitude of the damage is not fully understood and local authorities are overwhelmed. A national emergency has been declared.

c. **International humanitarian assistance.** A situation in an African country has placed a large number of lives at risk. The magnitude of the situation has overwhelmed local government, infrastructure and support facilities. To relieve human suffering and stop loss of life, the UN has passed a resolution calling for a multinational force (with Canadian contribution) to be formed that will deliver humanitarian supplies and support services for local government authorities and non-government organizations (NGOs).

d. **Surveillance / control of Canadian Territory.** Incidents of drug smuggling and landings of illegal immigrants on Canadian coasts have increased. The Cabinet directed the CF to assist in stemming the tide of illegal activities. CF units will assist the RCMP to identify, track, and, if necessary or required by law enforcement agencies, intercept "platforms of interest" before or after reaching Canadian territory.

e. **Evacuation of Canadians overseas.** An internal conflict between a country's government and an insurgent group has reached a level where it threatens the stability of the country and its general peace and order. Since it is possible that the insurgents could take hostages to further their cause, the Canadian government has decided to evacuate all Canadian citizens.

f. **Peace support operations.** Conflict has broken out between two bordering states. Over time the situation evolved into a prolonged stalemate. Both parties agreed to a UN-brokered ceasefire. NGOs have deployed into the area, and the UN passed a resolution to establish a UN force to conduct peace support operations along the border area to contribute to the establishment of an environment where peace building can take place. The Canadian government agreed to deploy CF personnel to aid this effort.

g. **Aid of the civil power.** Canada has been suffering through a drought and water rationing has been enforced. Minor disputes over water access have become more prevalent. As water has grown scarcer, the disputing groups have become organized. In at least one case a minor dispute has escalated creating large-scale unrest, including armed insurrections. Civilian authorities can no longer cope the situation and CF assistance has been requested and provided.

h. **National sovereignty/interests enforcement.** Discovery of precious metal deposits on the seabed close to the 200nm limit of Canada's west coast have led to a dispute over seabed rights. Canadian claims for extended jurisdiction have been rejected by a country, and deep seabed exploitation vessels from that country have begun operations just beyond the 200nm limit. A Fisheries and Oceans vessel with RCMP on board was sent to try to dissuade encroachment into Canadian jurisdiction, but instead it was turned back by small arms fire. Subsequently the country dispatched a frigate to protect her claims to exploitation of seabed resources. It also rejected Canadian calls for a cessation of seabed operations until the case had been resolved by international arbitration, labeling such action as obstructionism.

i. **Peace support operations.** Tension between two non-NATO bordering states has escalated to include armed conflict. One state is likely to attain an overwhelming victory over its opponent. The international community views this as unacceptable. This led to a resolution by the UN Security Council that a multinational force under UN command be formed and deployed to restore the previous situation. A coalition force is being established and Canada has agreed to deploy maritime, land and air force personnel abroad.

j. **Defence of North America.** A military superpower has emerged and become increasingly hostile to the West. A country of the Americas is affiliated with this superpower. This nation has become increasingly disruptive and has come under the control of criminal elements resulting in its national resources being focused on the production, sale and distribution of drugs to North American. The influx of drugs has increased crime in North American cities and there is concern that domestic criminal organizations in Canada and the US could engage in support of terrorist

activities at home. All diplomatic means of solving the problem have been exhausted. The UN is unable to get agreement on a resolution that would authorize a multinational coalition to rectify the situation. Consequently, US and Canada establish a joint force to eliminate the threat posed by the hostile country and establish conditions for democratic elections. The superpower has threatened retaliation if US/Canadian forces interfere with its ally. The government has directed DND/CF to defend Canada against possible incursions and attacks.

k. **Collective Defence.** Two neighbouring nations have a long-standing border dispute. A recent natural resources discovery within the area has rekindled the dispute—one nation has revived territorial claims for lands adjacent to the disputed border. Tension has increased and there have been a growing number of incursions by the neighbouring nation. NATO protests and sanctions have increased regional sympathies whereby the neighbouring nation has developed an informal military alliance with a number of local dictatorial regimes. Intelligence has learned that they plan to hold a large military exercise near the disputed area despite considerable diplomatic and UN efforts to head off a confrontation. The NATO nation under pressure has called upon its NATO allies to provide a credible deterrent force. The Canadian government has started preparations to enable replacement of combat losses in the Contingency Force to be made from existing forces.

The framework of scenarios can be mapped within the spectrum of conflict ranging from peacetime to war-fighting operations as defined in the previous section (see Figure 3 [Reference 3]). Spanning the framework across this spectrum assists DND and CF in identifying capabilities the CF may require in the future.

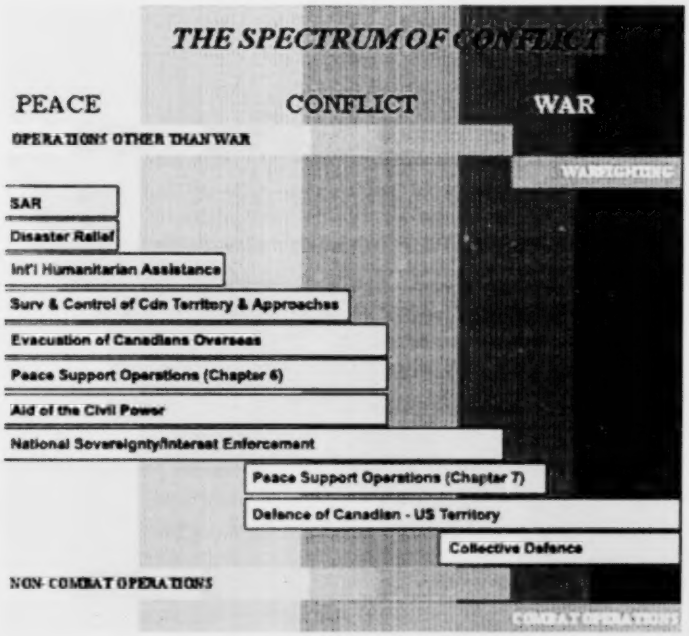

Figure 3: Spectrum of Conflict

4.3 UAV Organizational Structure

The CF UAV organizational structure for endurance UAVs is based on the CF UAV CONOPS (Maritime) [Reference 4]. The CONOPS (Maritime) focuses primarily on UAV operations in the maritime and littoral roles and is the first in a subset of CONOPS generated for the CF UAV program. Given the mission scenario is based on a CD OP/FISHPAT, this document provides the necessary direction regarding the CF UAV organizational structure for maritime operations. For TUAVs, the organizational structure is captured in the CF TUAV Operating Procedures [Reference 24].

The following sections summarize those details pertaining to the CF structure as well as command and control processes for UAV deployment. Since the US has a longer history regarding the utilization of endurance UAVs, the UAV organizational structure within the US armed forces is also in Appendix A for comparison purposes.

4.3.1 CF Structure

The CF force structure of a UAV unit (endurance and tactical classes) operates under the basic principals of a unit under the command of the Chief of the Air Staff (CAS). The CAS through 1 Canadian Air Division (CAD) is responsible for providing the infrastructure, personnel, and support similar to any other "air force" unit. As a result, 1 CAD personnel will form the core of a UAV unit whereby each of these established units would subsequently field completely self-sustainable and deployable UAV detachments. Given the dynamic nature of UAV employment, these detachments will incorporate personnel, financial, logistical, and equipment augmentation by other commands (e.g. army, navy, or other government departments) when they are tasked to support these commands.

In contrast, currently it is expected that Mini UAVs will be under the command of the Army and relegated as a Battle Group asset.

4.3.2 CF Command and Control

All UAV missions require the issuance of a tasking by an authorized commander. In accordance with the CF UAV CONOPS (Maritime), the three tasking categories utilized in the employment of CF UAV resources are:

a. **Tasking.** Written direction to perform a mission (typically issued in the form of an Air Tasking Order (ATO)) received prior to initiation of UAV operations;

b. **Re-Tasking.** Written or verbal direction from the designated command authority to change the mission or location of the UAV while it is airborne. Re-tasking only occurs when the new mission is assigned a higher priority than the current tasking; and

c. **Dynamic Re-Tasking.** This tasking is reserved for the UAV Mission Commander to immediately react to a changing situation as detected by the UAV during the course of either the initial tasking or re-tasking.

The following command structures for the each type of operation are based on the assumption that the endurance and tactical UAVs will be Air Force (AF) assets.

4.3.2.1 Domestic Operations

Since endurance UAVs are an AF resource, they fall under the command of the CAS. The CAS exercises full command of all AF resources as delegated by the Chief of the Defence Staff (CDS). Operational Command (OPCOM) of AF resources is exercised by the Commander 1 CAD. Operational Control (OPCON) is assigned to the Commanders Maritime Forces Atlantic/Pacific (MARPAC/MARLANT), in their capacity as coastal Formation Commanders, for the conduct of specific national UAV maritime operations within their areas of responsibility (AOR). The Commanders Maritime Air Component (Atlantic) and (Pacific) (MAC(A) and MAC(P)) are delegated the responsibility of exercising OPCON of assigned UAV assets supporting a maritime role. The roles and responsibilities of commanders exercising national authority are defined in present doctrine and guidance for air assets. Direct communications links between the UAV Mission Commander and designated command authorities are necessary; especially when OPCON and OPCOM reside with different commanders.

For national joint/contingency operations, the Deputy Chief of Defence Staff (DCDS) will appoint a Joint Force Commander (JFC) and, as required, the Commander 1 CAD will transfer OPCON to the appropriately designated Air Component Commander. These operations include counter drug operations, contingency support in the case of large-scale natural disasters, and aviation/marine disasters. Since UAVs have the capability to support national interests abroad (e.g., supporting JTF-2 boarding or assault operations), the chain of command must remain responsive to DCDS-directed operations requiring the use of UAV resources. Typically, these operations will be shifted to an appointed JFC via a Transfer of Command Authority (TOCA) of allotted UAV assets occurring between the Commander 1 CAD and the National JFC.

4.3.2.2 Peace-Support and War-Fighting Operations

For international contingency operations, OPCON will be transferred to the appropriate NATO or Allied Maritime Commander. In addition, the Commanders MAC(A) and MAC(P) have the authority to transfer OPCON to other NATO and Allied Commanders as a means to obtain required training and readiness for UAV crews. UAVs can be used for an assortment of roles as well as be quickly re-tasked in real-time to address changes in evolving operations at all levels of force structure. Consequently, the C2 structure must be clearly defined prior to the deployment/employment of UAVs.

The Sperwer TUAV, for instance, is under the command of the Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) Company Commander and will respond to the Brigade Commander's priority intelligence requirements, the Commander's critical information requirements and other requests for TUAV support. As part of Operation Athena (Section 4.4.4), control of the TUAV rests with the KMNB G3 and G3 ISTAR as tasked by the KMNB Commander. Mission requests are coordinated through the ISTAR Coordination Centre and the Target Acquisition Centre.

4.4 UAV MISSIONS

Literature defining UAV roles within the armed forces typically focus on the employment of endurance UAVs. This emphasis is due to the longer history experienced by this class of UAVs as demonstrated by the extensive operational portfolio of the Predator and Global Hawk. Traditional operational deployment of endurance UAVs have focused on completing ISR-related missions. While this strategy still holds true, advances in technology have extended the role of endurance UAVs beyond these traditional roles.

In addition to endurance UAVs, the mission scenario documented in this report introduces the notion of a family of UAVs—teaming Tactical and Mini UAVs with MALE UAVs to accomplish a littoral mission. Missions will vary among the different UAV classes; however, similarities exist whereby the smaller UAVs will perform more focused roles due to their limited range as compared to their larger cousins. To that end, the different classes of UAVs can be employed to complement one another within the confinements of the entire mission. For instance, MALE UAVs can provide continuous 24/7 surveillance of a large area of interest whereas the smaller UAVs can provide support through the positive identification of unknown contacts detected by the MALE especially when weather conditions are not optimal.

In conjunction with their different roles, UAVs are assigned to different organizations. MALE UAVs are primarily an operational level asset although their inherent payload flexibility enables them to be used for either strategic or tactical level missions as well. TUAVs are generally a formation or brigade level asset whereas Mini UAVs are typically a brigade or unit level asset.

The following section proposes a number of operations or roles for employing UAVs. Some missions propose novel uses for the UAV whereas others have been operationally played out. Endurance UAVs have seen active participation in recent US operations such as Operation Allied Force (Kosovo), Operation Southern Watch (Iraq), Operation Enduring Freedom (Afghanistan), and Operation Iraqi Freedom (Iraq). Within Canada, a MALE UAV (I-Gnat) was deployed to augment the combined CF-civilian security force during the G8 Summit in Kananaskis, Alberta. The CF is also currently deploying a Tactical UAV in Kabul, Afghanistan in support of their peacekeeping mission.

The UAV tasks are grouped according to the three CF mission types described in Section 4.2.2. This is not intended to be a comprehensive list of all possible UAV missions. In addition, some of the missions listed below may be reserved to a particular class of UAV.

4.4.1 Domestic Operations

Within Canada, UAVs can provide support for numerous domestic operations that are typically ISR-related. Examples of UAV missions include:

a. **Counter Drugs Missions.** Support of counter drugs can be accomplished in a variety of environments by UAVs. UAVs can aid in detection, identification, tracking, and imaging of drug trafficking activities.

b. **Disaster Recovery.** UAV support can be provided as early as possible to assist civil authorities to understand the size and complexity of natural disasters, and assist in the recovery planning. Support during fires could also be a critical role for UAVs, identifying new outbreaks and direction of the fires.

c. **Homeland Security.** UAVs can be deployed to watch coastal waters, patrol the nation's borders, and protect major oil and gas pipelines. To that end, UAVs can play an important role in developing and maintaining situational awareness including the Recognized Maritime Picture.

d. **Long-duration law enforcement surveillance.** Similar to supporting counter drug operations, endurance UAVs can assist law enforcement for situations that require long-duration law surveillance, a task performed by manned aircraft during the October 2002 sniper incident near Washington, D.C. The Transportation Department has looked at possible security roles for UAVs, such as following trucks with

hazardous cargo, while the Energy Department has been developing high-altitude instruments to measure radiation in the atmosphere.

e. **Search and Rescue.** Until assistance arrives, UAVs can help locate as well as maintain position of distressed vessels and lost personnel.

4.4.2 Peace Support Operations

Similar to the domestic operations, peace support operations that are typically augmented with UAVs involve ISR. This includes:

a. **United Nations Treaty Monitoring.** A variety of UN missions can be accomplished with endurance UAVs to ensure compliance with UN resolutions. They can alert UN authorities of violations while providing safe and NRT surveillance of areas of interest.

b. **Blockade and Quarantine Enforcement.** Economic, military and drug enforcement blockade and quarantine missions may be supported by UAVs to free up enforcement patrol assets for other missions.

c. **Humanitarian Assistance.** Missions in support of humanitarian aid planning can be done virtually anywhere at anytime. The UAV can provide information on the number of people displaced and survey weather damage.

d. **Sensitive Reconnaissance Operations.** SRO is a non-wartime reconnaissance operation conducted by manually or remotely operated Department of Defence (DOD) platforms involving significant military risk or political sensitivity. The level of sensitivity is determined by analyzing the collection objectives, means of collection, and area of operations.

4.4.3 War-Fighting Operations

The emphasis of endurance UAV missions for the US Armed Forces is firmly entrenched on wartime use. DOD plans call for endurance UAVs to play an integral role in battlefield operations. Endurance UAVs can support war-fighting operations such as:

a. **Near-Real-Time (NRT) Surveillance.** UAVs can be used for NRT surveillance of maritime approaches, offshore territories, etc. UAVs can aid in identification, tracking, and imaging of suspected targets, providing NRT surveillance information. Provision of this information in a timely manner will allow manoeuvre of land, sea and air assets to identify and prosecute the target if required. It will also allow the ADF to develop a longer-term picture of the trends occurring in our maritime approaches and northern landmass.

b. **NRT Targeting and Precision Strike Support.** Endurance UAV systems will offer opportunities to fulfill time-sensitive targeting requirements by providing a means to shorten the targeting cycle for interdiction campaigns through NRT precise location of mobile enemy forces. The ability to locate, identify, and quickly destroy mobile targets will eliminate the enemy's ability to re-supply and manoeuvre forces. Endurance UAV sensor resolution and accuracy will enable expanded use of precision guided munitions, improving battlefield efficiency.

c. **Precision Strike.** In addition to providing strike support, UAVs have added strike mission to its repertoire. For example, the Predator stalked Taliban and Al Qaeda

leaders in Afghanistan and Yemen and then proceeded to strike these targets with Hellfire missiles. Most recently, the Predator has been credited with two strikes in Operation Iraqi Freedom in March 2003. One strike targeted an anti-aircraft vehicle while another fired its Hellfire missile at a TV satellite dish in downtown Baghdad. Other potential strike operations include suppression of enemy air defences (SEAD).

d. **NRT Combat Assessment.** UAVs provide NRT combat assessment of on going operations to the battlefield commander. Immediate feedback of planned and executed operations will assist with the efficient prosecution of campaigns and minimize the fog and friction of war.

e. **Enemy Order of Battle Information.** UAVs provide a rapid means to develop and track enemy order of battle information, especially in areas where information is sparse.

f. **Battle Damage Assessment (BDA).** UAVs can provide high resolution, NRT assessment of target damage. Immediate feedback will support the warfighter's immediate re-strike requirements.

g. **Intelligence Preparation of the Battlefield (IPB).** UAVs can survey areas of interest in preparation for battle or amphibious assaults and landings, as well as significantly enhances Indications and Warning capability.

h. **Special Operations Support.** Tasks in support of special operations can provide real-time data for mission planning. UAV assets can be used to track high-interest, sea-going vessels, high-interest individuals or organizations. UAV information also has the potential of providing direct imagery down links to ground special operations units that need to "look beyond the horizon" for ingress, targeting, or egress from hostile areas.

i. **Single Integrated Operational Plan.** Endurance UAVs have the potential to assist missions in support of planning and employment of strategic forces, countering weapons of mass destruction, and nuclear strike assessment.

j. **Communications.** The high altitude and long endurance of the UAV make it an excellent platform for C4I relay and broadcast systems. UAVs have potential to significantly enhance dissemination of battlefield intelligence and C2 information to all areas and levels of command. Conversely, UAVs may also support jamming of enemy communications as well as detecting hostile electronic emissions to aid in assessing their location, identification, and intentions (electronic warfare).

k. **Air-to-Air Refueling.** Large UAVs could take on the aerial refueling task now performed by existing tanker aircraft. The flight profiles flown by tanker aircraft are relatively benign and they tend to operate far from enemy air defences. Except for operating the refueling boom, the refueling crew's primary job is to keep the aircraft flying straight, level, and at a steady speed. The Global Hawk's recent trans-oceanic flights demonstrate the ability of current UAVs to fly missions analogous to aerial refueling missions.

l. **Air-to-Air Combat.** DOD is experimenting with outfitting UAVs with the sensors and weapons required to conduct air-to-air combat. In fact, a Predator has reportedly already engaged in air-to-air combat with an Iraqi fighter aircraft. In March 2003 it was reported that a Predator launched a Stinger air-to-air missile at an Iraqi MiG before the Iraqi aircraft shot it down.

m. **Cargo Transport.** UAVs such as the Army's Shadow have been studied as delivery vehicles for critical medical supplies needed on the battlefield.

n. **Joint Operations.** UAVs will team up with manned aircraft to carry out operational missions. The Navy is considering pairing a UAV such as Global Hawk or the Predator B with its planned multi-mission maritime aircraft (MMA), as a replacement for its aging long range patrol aircraft, the P-3C Orion. The Army envisions helicopters such as the AH-64 Apache and RAH-66 Comanche controlling UAVs and receiving direct video feeds from the UAV.

4.4.4 Summary of CF UAV Operations/Exercises

The CF has seen limited exposure to UAVs, with past operations focusing on employment of UAVs for ISR-related activities. The following are the foremost CF events that have involved UAVs.

a. **Robust Ram (April 2002).** This exercise was conducted at Suffield, AB with three UAV systems (Aeronautical Systems' I-Gnat, Bombardier's CL327, and AeroVironment's Pointer) employed in support of a brigade training exercise. The primary objective was to evaluate the military utility of the three candidates with the best one being employed in a security role for the G-8 Summit. Each UAV type was explored in conjunction with live-fire armoured/mechanized infantry assaults.

b. **G-8 Summit (June 2002).** Security for the G-8 Summit held in Kananaskis, AB was augmented with the I-Gnat MALE UAV. The UAV was flown in support of troops deployed within the area. A significant undertaking was coordinating the conduct of military UAV surveillance within civil airspace. A valuable lesson learned was the requirement for multiple ground control stations to facilitate the dissemination of sensor data.

c. **Pacific Littoral ISR Experiment (July 2003).** The objective of PLIX was to assess the military utility of a multi-sensor UAV within an integrated ISR architecture to support the construction and dissemination of an experimental Recognized Maritime Picture (RMP) as well as execute surveillance tasks within a specific littoral operations area. The UAV flown during PLIX was the EAGLE 1 UAV from Israeli Aircraft Industries.

d. **Operation Athena (October 2003).** To support the NATO-led International Security Assistance Force (ISAF) peacekeeping operation in Kabul, Afghanistan, the CF troops are employing tactical UAVs (Sperwer) for reconnaissance and surveillance.

Future UAV experiments include the Atlantic Littoral ISR Experiment to be conducted in 2004 off the east coast of Canada.

4.5 UAV/UCAV System Description

As part of the mission scenario, it is necessary to describe the relevant features of the aircraft and mission equipment that are expected to comprise each class of UAV system. The definition of an assumed air vehicle is necessary as the basis for any further human factors evaluation.

Depending on the mission, there are a wide variety of operational UAVs that can be employed to best suit the objective. The UAV Maritime Concept of Employment [Reference 21] categorizes UAVs into five categories: HALE, MALE, Tactical, Mini, and Micro (see Table 2). Similarly, EURO UVS [Reference 6] has developed a more comprehensive scheme for categorizing UAVs based on parameters such as operational range, flight altitude, endurance, and take-off mass. This scheme covers all existing UAVs, as well as those that are currently under development.

Table 2: Classification of UAVs

Category	Flight Alt (ft)	Endurance (hr)	Programs
Micro (μ)	<2 000	<2	Wasp
Miniature (Mini)	<2 000	<2	Grasshopper, Dragon-Eye, Pointer
Tactical	<15 000	<24	Shadow 2000, Pioneer, Eagle Eye, CL-237
Medium Altitude Long Endurance (MALE)	15 000 to 45 000	>24	MQ-1 Predator, Eagle 1, Heron
High Altitude Long Endurance (HALE)	>45 000	>24	RQ-4 Global Hawk, Pathfinder

The CF UAV CONOPS (Maritime) has identified the Maritime aspects of ISR, for surface targets of interest in a littoral environment as vital missions for a UAV. Currently, these littoral roles are being conducted by Long Range Patrol Aircraft (LRPA) such as the CP-140. However, their characteristics of size, endurance, manning and sensor suite and most significantly cost, limit their employment. UAVs can offload a large portion of demands placed on a LRPA to fulfill a close range patrol operations. The result is a marrying of resources (both manned and unmanned) to patrol and secure Canadian sovereign interests. As a result, the mission scenario was written to accommodate the capabilities of a Medium Altitude Long Endurance UAV.

In addition, the CF UAV program outlined for this CONOPS currently employs (but is not limited to) a remote controlled, long endurance, fixed wing, medium altitude platform operating from a conventional runway or hard surface. Employing this type of UAV within the mission scenario will help to validate the CONOPS.

In support of the MALE UAV in its conduct of the mission in the littoral environment, the scenario will also involve the deployment of Tactical and Mini UAVs. This capability is expected to be present within the CF in the future.

Although the goal of the mission scenario is not to suggest a particular UAV to be employed during the conduct of the mission, it can be assumed that the

a. MALE UAV will have similar characteristics to the MQ-9 Predator or Predator B-ER from General Atomics Aeronautical Systems, Inc. (www.uav.com/home/index.html);

b. Tactical UAV will have similar characteristics to the Eagle Eye from Bell Helicopters (www.bellhelicopter.com/); and

c. Mini-UAV will have similar characteristics to the Seascan from The Insitu Group (www.insitugroup.net/).

Accordingly, details regarding each UAV system are presented to augment the description of potential UAV configurations for the mission scenario. In addition, describing the UAV system as the assumed air vehicle is a good method of ensuring all major system functions have been identified. Additional information on the Predator UAV system is provided in Appendix B.

4.5.1 Predator System Overview

The Air Force's Predator is the only reconnaissance system available in the U.S. inventory that can provide near real-time video imagery day or night in all weather conditions via satellite worldwide without exposing pilots to combat fire. As the first successful unmanned aircraft surveillance program, Predator provides tactical and strategic intelligence to operational commanders worldwide.

The RQ-1A Predator UAV (see Figure 5 [Reference 7]) began as an Advanced Concept Technology Demonstration (ACTD) in 1994 and then became first DOD ACTD UAV to transition to the Air Force in 1997 after successfully completing missions over Bosnia in 1996. Predator became the first American UAV to designate a target for laser-guided bombs launched from an A-10 ground-attack aircraft. It is also the first UAV in history to fire offensive weapons against enemy combat forces. Due to its added capabilities of laser designation and missile-firing, the US Air Force (USAF) changed the Predator's military designation from RQ-1 (reconnaissance unmanned) to the MQ-1 (multi-mission unmanned) in February 2002. General Atomics also upgraded the capabilities of the original Predator thereby changing its designation to RQ-1B/MQ-1B. Upgrades included:

a. an improved relief-on-station system;

b. secure air traffic control voice relay;

c. Ku-band satellite tuning;

d. an Air Force Mission Support System;

e. a more powerful turbocharged engine; and

f. wing de-icing systems to support year-round operations.

All future procurement will be the MQ-1 variant as the RQ-1 will be phased out from operational usage through attrition.

The RQ-1/MQ-1 Predator has operationally proved itself in recent conflicts such as Balkans (2001), Iraq (2001), Kosovo (1999), and Afghanistan (2002). In these theatres, the Predator has enjoyed considerable success in the global war against terrorism, increasing the situational awareness of other aircraft such as the Air Force's AC-130 gunship, and employing its revolutionary armed strike capability against Al Qaeda and Taliban leadership.

Since the introduction of the RQ-1/MQ-1 Predator, General Atomics in cooperation with NASA has evolved its design into the Predator B series (see Figure 6 [Reference 7]). The B variant is a larger version of its predecessor with improvements in altitude, payload, speed, and range. Predator B development began with the proof of concept, Predator B-001. The B-001 is powered by a turboprop engine with a standard Predator airframe and stretched wings. Its maiden flight was completed in February 2001. The Predator B-002 is virtually identical to the B-001

with the exception of a turbofan engine resulting in increased speed but reduced endurance. The B-002 also has a decreased payload capacity and increased ceiling. The third production version is the Predator B-003 or Predator B Altair. This variant has a new airframe with increased wingspan, a takeoff weight of 7,000 lbs, the same turboprop engine as the B-001, a payload capacity of 3,000 lbs, a maximum ceiling of 52,000 ft, and an endurance of 36 hrs.

Figure 5: RQ-1 Predator UAV

In October 2001, the USAF acquired two Predator B prototypes for evaluation with follow-up orders for production. The USAF designated these UAVs as the MQ-9B Predator with the nickname "Hunter-Killer". The USAF believes this asset will provide an enhanced "deadly persistence" capability, with the UAV loitering over a combat area waiting for a target to present itself. In this role, an armed UAV complements manned strike aircraft. A manned strike aircraft can be used to release larger quantities of ordnance on a target. The cheaper UAV can operate continuously while carrying a light warload to engage targets of opportunity.

The USAF anticipates that the Predator B will fulfill a niche between its predecessor and the Global Hawk HALE UAV. The Predator B is not seen as a replacement for the Global Hawk since the latter flies at a higher altitude and carries a heavier payload. In addition, the Predator B may need to employ a highly specialized payload (e.g. electronic intelligence system) without attracting the same attention as the larger Global Hawk. In addition, the USAF does not want to tie up a whole Global Hawk for a small payload.

Figure 6: Predator B UAV

Similarly, the Predator B is not seen as a replacement for the RQ-1/MQ-1 Predator. To provide video to command elements, the USAF typically flies the Predator between 15,000 and 25,000 ft. The Predator B flies higher and cannot deliver equivalent quality video. The USAF is examining whether high-definition television can provide improved resolution at higher altitudes, but doubt it would match the performance of the RQ-1 Predator. However, Predator B can get above the weather that often degrades Predator's performance while carrying a larger payload. One option is flying the Predator B into a target area at 45,000 ft and then dropping down to a lower altitude for imaging. However, USAF officials believe the Predator B's performance (e.g. endurance) would suffer if operated at 25,000 ft. for extended periods since the aircraft has been optimized for operations at the higher altitude.

The issue of arming UAVs is another reason the USAF does not want to blend Global Hawk and Predator. The USAF has armed the Predator (see Section B.2.3). The objective is not to arm the Global Hawk so that it remains purely a surveillance and reconnaissance system which can fly in peacekeeping missions over other countries. Getting overflight permissions for a system capable of being armed would be more difficult.

4.5.2 Bell HV-911 (Eagle Eye) System Overview

The Bell HV-911 (Eagle Eye) is a Vertical Takeoff and Landing Tactical Unmanned Aerial Vehicle (see Figure 7 [Reference 29]). This asset is a short-range shipboard deployable UAV. Once in service, the US Coast Guard (USCG) plans to employ the asset to extend the detection, classification, and identification capability of its National Security Cutters. Under the USCG's CONOPS, the primary role of the Eagle Eye is to classify and identify targets from ships

equipped with High Frequency Surface Wave Radar. This capability can be used to perform maritime homeland security, search and rescue, law enforcement, marine environmental protection, and military preparedness.

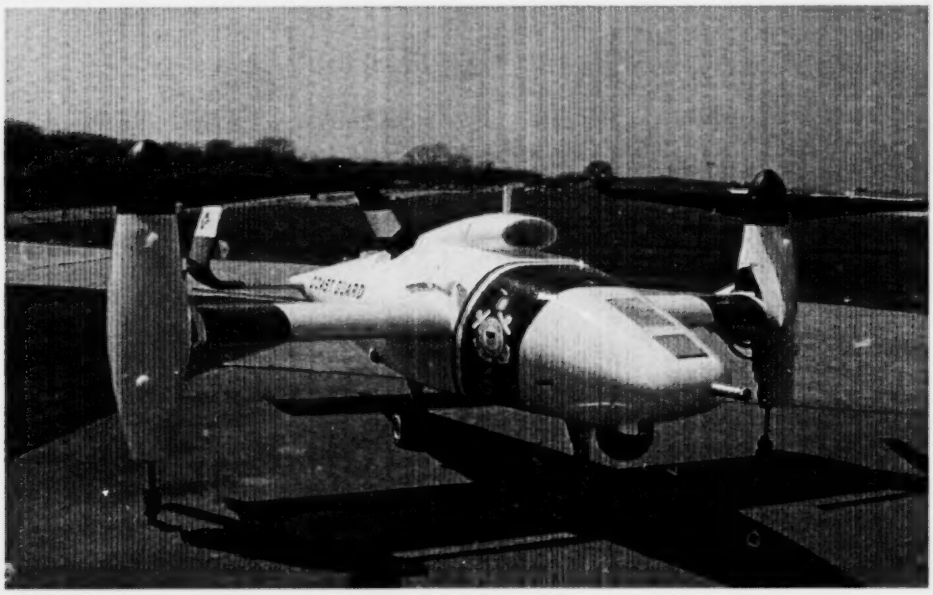

Figure 7: Bell Eagle Eye UAV

The Eagle Eye UAV was originally developed as part of the DOD Tilt-Rotor UAV System program in the early 1990s. The demonstrator was created to validate and refine basic flying qualities and performance characteristics of a small scale Tiltrotor with the potential for future applications to VTOL UAV missions. The Eagle Eye first hovered in early 1992 with subsequent tests being conducted for the US Navy at Yuma Proving Grounds in Arizona during 1993. In 1998, the US Navy selected the Bell Eagle Eye as one of three UAVs for its VTOL UAV Demonstration Program. The objective was to demonstrate the performance and maturity of the prototype and its control system. The Eagle Eye UAV completed the test and evaluation without incident while meeting all objectives. In 1999, Bell submitted an unmanned tiltrotor concept as an entrant in the joint US Navy and Marine Corps VTOL Tactical UAV initiative. The UAV design, designated TR911X, is a derivative of the Eagle Eye demonstrator. The TR911X demonstrated that it is capable of cruising at speeds of 340 km/h and climbing to altitudes of up to 6000m.

In February 2003, the Bell Eagle Eye was selected for the UAV portion of the USCG Integrated Deepwater System (IDS) [Reference 27]. The IDS will modernize and replace aging ships and aircraft as well as improve C2 and logistics systems. By 2005, 3 Eagle Eye prototypes will be built for testing. Following the success of the 7/8 scale Eagle Eye prototype, Bell announced in November 2003 an effort to design, build, and fly a full scale version of the UAV within one year.

4.5.3 Seascan System Overview

The Seascan UAV (see Figure 8 [Reference 28]) was designed to assist with operations such as aerial reconnaissance at sea, search and rescue, and coastal patrol that have traditionally been reserved for ships large enough to accommodate a helicopter. The Seascan's size attempts to make UAV deployment practical from a wide range of vessels while offering long endurance, and eliminating risk to aircrew. A standard Seascan system includes two air vehicles (AV) with storage/shipping containers, a ground control workstation, communications systems, a catapult launcher, a 'Skyhook' recovery system, and training. Seascan will enter routine shipboard service in early 2004. It will allow reconnaissance at a fraction of the cost of current sea-based helicopters and fixed-wing aircraft, with much longer endurance, for a wider range of ships.

Figure 8: SeaScan UAV

Currently, The Insitu Group are working in conjunction with Boeing to develop the next generation UAV, ScanEagle. ScanEagle is based on the Seascan aircraft and draws on Boeing's systems integration, communications and payload technologies.

4.5.4 Air Vehicle Characteristics

The characteristics for each type of air vehicle are summarized below in Table 3. Blank cells indicate that the specification data was not readily available.

Table 3: AV characteristics

Characteristic	MQ-9 Predator[1]	Eagle Eye[2]	Seascan[3]
Dimensions			
Wingspan	66 ft (20.2 m)	15.2 ft (4.6 m)	10 ft (3.04 m)
Length	36.2 ft (11 m)	17.9 ft (5.3 m)	3.9 ft (1.2 m)
Height	11.8 ft (3.6 m)	5.7 ft (1.7 m)	
Weight			
Fuel	3000 lbs (1364 kg) - int 4000 lbs (1816 kg) - ext		9.5 lbs (4.3 kg)
Payload	1000 lbs (340 kg)	200 lbs (90.7 kg)	7 lbs (3.2 kg)
Max Takeoff	6500 lbs (2955 kg)		
Speed			
Cruise		370 km/hr (200 kts)	85 km/hr (48 kts)
Loiter		167 km/hr (90 kts)	
Maximum	407 km/hr (220 kts)	407 km/hr (220 kts)	126 km/hr (68 kts)
Altitude			
Maximum	50 000 ft. (15 240 m)	20 000 ft. (6 096 m)	16 000 ft. (4 877 m)
Operating	> 25 000 ft	<20 000 ft	<16 000 ft
Mission Duration Operating Radius	16 hrs on station at 650 nm		
Maximum Endurance	52 hours	4 – 6 hours	6 hrs (15 hrs w/ no reserves)
Payload	Radar EO/IR	Radar EO/IR	EO camera or IR camera or CBRN sensor or EW sensor
Imaging Capabilities			
Detect	400 x 400 km	30 x 30 km	5 x 5 km
Classify	200 x 200 km	20 x 20 km	
Identify	10 x 10 km	10 x 10 km	

[1] MQ-9 Predator specifications from Reference 20.

[2] Eagle Eye specifications from Reference 27

[3] Seascan specifications from Reference 28.

4.5.5 Payload

To accomplish the typical ISR mission, the dominant payload in the majority of UAVs, including the Predator, comprises electro-optical and infrared cameras as well as a synthetic aperture radar imagery sensor. This gives the UAV a day/night, all-weather (within aircraft limits) reconnaissance capability. The assumed imaging capabilities for each UAV system are presented above in Table 3 as per Reference 30. To illustrate current capabilities, existing sensors compatible with each UAV class are presented where possible. This is not to suggest that these exact sensors must be employed as part of the mission scenario.

4.5.5.1 Electro-Optical/Infrared

To assist with the detection, classification, and identification of targets, each class of UAVs will carry a variation of an EO/IR payload. The EO capability in UAVs is typically accommodated with two cameras: one for daytime operations and another for nighttime. The IR camera employs thermal imaging techniques which uses tiny differences in temperature (fractions of a degree C) within a scene to build a detailed picture of the situation.

Reference 25 indicates the MALE UAV EO/IR payload to be employed as part of ALIX should be capable of identifying a 3m target in either EO or IR mode from a distance of 20km when operating at an altitude greater than 20 000ft ASL. In addition, the payload must possess automatic target tracking feature in both modes. As a minimum, these same capabilities will be supported by the MALE UAV employed in the mission scenario. Appendix B describes the EO/IR sensors employed by the MQ-1/RQ-1 Predator as well as the anticipated capabilities for the Predator B since the exact EO/IR payload for this variant has yet to be determined.

To fulfill its role within the mission scenario, the VTUAV will possess EO/IR capabilities analogous to the Raytheon AN/AAS-52 Multi-Spectral Targeting System (MTS) Ball (www.raytheon.com/products/mts/). The MTS is a multi-use EO, IR, and laser detecting-ranging-tracking set. This EO/IR system provides long-range surveillance, target acquisition, tracking, rangefinding, and laser designation. The MTS enables automatic image optimization that maximizes displayed image information thereby enhancing both situational awareness and long-range surveillance. Another sensor with similar capabilities is the Wescam MX-20 Ball (www.wescam.com/products_services_1h.asp).

Finally, the Mini UAV can employ either an EO or IR camera. The current design of the Seascan incorporates a digital video camera integrated into an inertially-stabilized pan/tilt nose turret. Visible or IR cameras can be fitted for day and night operation. The daylight camera has an acuity 50% better than that of the unaided eye at the telescopic end. It can resolve objects such as small boats and logs from at least 5 miles away. The operator can command the camera to pan back-and-forth for wide-area search, or to remain locked onto an object while the aircraft maneuvers.

4.5.5.2 Radar

A standalone EO/IR payload by itself is not sufficient in all climates. Three environmental conditions that render this imaging insufficient are heavy cloud, thermal crossover, and thermal 'grey-out'. The introduction of complementary payloads such as SAR helps to overcome these deficiencies. The SAR complements the EO/IR payload since it provides both the wide area coverage and the weather penetration that the EO/IR device cannot. However, the SAR is not a substitute for the former since it cannot resolve the fine details that are essential for target identification. The radar related capabilities are reserved for the MALE and Tactical UAVs. The Mini UAV will not possess this functionality since it is not required given the operational role for this class of UAV within the confinements of the mission scenario.

For ALIX, Reference 25 indicates that the radar on the MALE UAV be capable of detecting and tracking multiple airborne targets, maritime surface vessels and IFF targets. In addition, the radar must have the capability to detect and monitor local weather as well as Maritime MTI. The radar must be able to detect a $1m^2$ target in surface wave conditions up to Sea State 5. The radar system must have the ability to detect, localize, track and classify surface vessels from altitudes >20,000 ft ASL through 360 degree azimuth. Detection ranges must meet or exceed the following requirements:

a. 10 m surface vessel – 80 km

b. 30 m surface vessel – 160 km

c. $1m^2$ target – 25 km

Similar to the EO/IR payload, it is anticipated that the MALE UAV will as a minimum possess the same capabilities as its ALIX counterpart. The Predator UAV has historically employed a SAR payload to perform these functions as detailed in Appendix B.

The TUAV will possess radar capabilities that are in-line with the Telephonix 1700. Although, current indications are that this payload will be used primarily for traffic avoidance.

4.5.5.3 Additional payloads

In addition to the aforementioned imaging payloads, there is other equipment that is (or can be) equipped for UAVs. Some examples include:

a. **Anti-ice kits.** These kits enable endurance UAVs to fly through cloud layers in order to operate above the clouds. This capability is essential for maritime off-shore operations such as the one depicted in the mission scenario.

b. **Nuclear, Biological, Chemical (NBC) sniffers.** These payloads allow UAVs to detect trace amounts of NBC agents without placing personnel within harm's way.

c. **Mini UAVs.** In August 2002, a conventional Predator successfully launched a FINDER (Flight Inserted Detector Expendable for Reconnaissance) UAV, a 57-lb satellite guided system with sensors while. This suggests using the larger Predator as a "mothership" that can send either mini-UAVs into hostile airspace for close-in targeting assistance or expendable UAVs with specialized sensors into regions contaminated by NBC agents.

d. **Electronic Warfare (EW) sensors.** This type of payload can assist with the gathering of electronic intelligence (ELINT) and communications intelligence (COMINT) by monitoring radar emissions as well as voice and data communications generated by the threat.

e. **Weapons.** There is much discussion regarding the arming of UAVs to expand their role within the armed forces. For instance, the Predator has been armed with Hellfire missiles and will host other munitions in the future (see Section B.2.3 for more details).

4.5.6 Ground Control Station

The UAV system will include a Ground Control Station (GCS) that is responsible for mission planning, aircraft mission control, and subsystem management (sensors, communications, and defensive systems). The GCS will be capable of re-tasking the UAV in

flight and change the sensor's areas of interest. In other words, the GCS provides the infrastructure and capabilities to act as the Mission Control Element for the UAV.

Current ground control stations for different UAV systems are not interoperable with one another due to their standalone design. To address this deficiency, the Tactical Control System (TCS) concept was devised. The TCS objective is to enable a UAV operator that is trained on one system to control different types of UAVs and/or UAV payloads with minimal additional training. The scalability of TCS introduces five levels of discrete control:

a. **Level 1:** Indirect receipt of secondary imagery and/or data;

b. **Level 2:** Direct receipt of payload data by a control station;

c. **Level 3:** Level 2 interoperability plus control of the UAV payload by a control station;

d. **Level 4:** Level 3 interoperability plus UAV flight control by a control station; and

e. **Level 5:** Level 4 interoperability plus the ability of the control station to launch and recover the UAV.

Primary imagery is the original data received at the GCS through a direct connection with the AV sensors. Secondary imagery is the sensor data that is received indirectly from another GCS via a communication network. Within the mission scenario, it is assumed that the following control levels will be supported for the individual UAVs:

a. For the MALE UAV, the ground-based MCE will maintain Level 5 control. Whereas, the airborne and ship borne MCEs would contain a subset of the ground-based GCS and consequently support Level 3 control of the MALE.

b. For the VTUAV and Mini UAV, the airborne and ship borne MCEs will provide Level 5 control.

All control stations will be compliant with STANAG 4586 "Standard Interface of the Unmanned Control System for NATO UAV Interoperability".

4.5.7 Communications

Communication for a given UAV system typically includes the following:

a. **Internal Communications.** Two-way communication between the AV and GCS includes the data downlink (transfer of imagery and telemetry data from the AV to the GCS) and the C2 uplink (transfer of mission commands from the GCS to the AV); and

b. **External Communications.** This characterizes the communications between the GCS and the rest of the operational community.

All communication links will be compliant with the appropriate standards including STANAG 7085 (Interoperable Data Links for Imaging Systems) and STANAG 4609 (NATO Digital Motion Imagery Standard).

4.5.7.1 Internal Communications

To relay data between the MALE AV sensors and the ground control station, the UAV system will employ both Line of Sight (LOS) and beyond line-of-sight (BLOS) capabilities. These are standard capabilities employed by endurance UAV programs. In contrast,

communications between the Tactical and Mini AVs and their respective MCE will be reserved to LOS.

It is expected that the LOS capabilities for the UAV will be Common Data Link (CDL) compatible as there is an effort to migrate all UAVs (tactical and above) to this format. Currently the MALE Predator employs an analog C-band LOS data-link (see Section B.3 for details). It is believed that a CDL link will offer 10.72-45 Mbps over distances up to 200 km.

For a BLOS communications between the GCS and MALE AV, the UAV system will employ capabilities comparable to the Ku-band SATCOM data-link to relay colour video in real time to commanders. Similar to the LOS communications, there is a thrust to move BLOS capabilities to CDL-compatible formats.

It is assumed that the both LOS and BLOS capabilities for all UAV systems will satisfy the mission requirements for timeliness and speed of transfer.

4.5.7.2 External Communications

Within the Predator UAV system, external communications are via HF/UHF/VHF (voice/data), cellular/landline telephones, and hardwire connectivity with the TROJAN SPIRIT II (TS II) satellite communication terminal. Details on the TS II are provided in Appendix B. Other SATCOM systems may be employed to link the GCS to an intelligence architecture.

4.5.8 Launch and Recovery Element

The Launch and Recovery Element (LRE) can be viewed as a subset of the MCE, providing the functionality for mission planning and air vehicle command and control. In contrast to the MCE, the LRE does not possess any wide-band data-links or image processing capability. However, the LRE does comprise a Differential Global Positioning System (DGPS) system for precision navigation for ground operations, take-off, and landing. The LRE mission planning capability is assumed to be fully redundant with the MCE capability; therefore, the LRE can make updates to the mission plan received from the MCE prior to launch or while enroute to/from the handover point. In addition, the LRE is responsible for co-ordination with local and en-route air traffic control facilities. The LRE may not be co-located with the MCE to provide a split-site deployment option which in turn offers operational and/or logistical flexibility.

The LRE typically employs one of three categories of launch and recovery techniques: prepared surfaces, point, and airborne. Each offers its own advantages and disadvantages. Given the size of the Predator, launching is performed through a conventional take-off from a prepared surface such as paved runway under direct line-of-sight control. For landing on a conventional runway, the Predator employs retractable landing gear, nose wheel steering, and brakes. The Eagle Eye is a tiltrotor; therefore, it has minimal requirements with respect to take-off and landing surfaces. Finally, the Seascan utilizes point techniques for launch and recovery. Specifically, this Mini UAV launches at about 50 kt with a low-pressure pneumatic catapult. Retrieval is done with the Skyhook whereby the AV flies into a single line suspended by a boom over the water and a hook on the wingtip grabs the line.

4.5.9 Level of Autonomy

Autonomous Operations (AO) is a current capability-push by both the US Navy in the Office of Naval Research's AO Future Naval Capability initiative and the US Air Force as part of the Air Force Research Laboratory's (AFRL) Sensorcraft initiative. In 2000, the AFRL defined ten Autonomous Control Levels (ACLs) in response to the OSD Fixed Wing Vehicle Initiative's

need for an autonomy metric, as display in Figure 13 [Reference 13]. In parallel with developing the technology for AO, the Services were told to evolve their doctrines for employing it. As one can see, the future development of UAVs in the US is forecasting a steep increase in autonomy. Current operational programs experience level 2-3 autonomy. It is this same level of autonomy that is assumed to exist in the baseline UAV system for the proposed mission scenario.

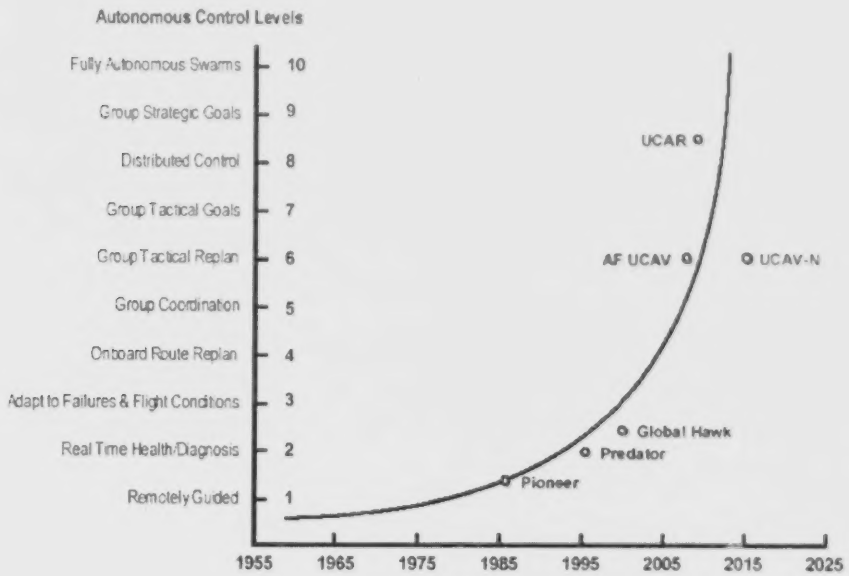

Figure 13: Levels of Autonomy

The Global Hawk UAV provides a good example of level 2-3 autonomy. The contingency management capability (level 3) built into this UAV addresses failures such as loss of data-links, loss of navigation, and loss of flight computers. Pre-programmed decision trees are built to address each potential failure during each part of the mission. For each case identified in this matrix, a corrective action is identified and coded into the system software. In addition, Global Hawk flies autonomously from takeoff to landing and in any weather—a capability that is not supported by the Predator.

Both DARPA UCAV programs (AF UCAV and UCAV-N) are advancing the capability of multi-vehicle co-operation (level 6 autonomy). This will be accomplished through inter-vehicle data-links for passing information such mission plan updates as well as target designation information. In turn, this information will be used to coordinate the operational activities. The UCAV-N is envisioned to be multi-mission capable—focusing on tactical surveillance and evolving to SEAD/strike system. Similarly, the AF UCAV will be designed to perform SEAD operations.

The DARPA/Army Unmanned Combat Armed Rotorcraft (UCAR) looks to attain level 8-9 autonomy. This unmanned attack helicopter is being developed for armed reconnaissance

and attack missions. The UCAR is advancing the degree of autonomy to include interpretation of high level mission tasking. The system will be able to develop specific mission objectives based on general mission objectives. In addition, it will be capable of collaborating with other manned and unmanned Army systems. This collaboration will not only include information sharing but also collaborative search, target identification, target prosecution, and BDA.

In addition to the aforementioned AV autonomy, there is much discussion regarding the need to improve sensor autonomy. For example, automatic target cueing explores the ability of sensors to search for targets autonomously based on characteristics defined in a target library.

4.6 Operators

According to the CF UAV CONOPS (Maritime), force generation falls under the Commander 1 CAD who in turn is responsible for providing combat ready crews and combat capable aircraft. Based on previous lessons learned from conducting UAV operations in and outside of Canada (see Section 4.4.4), the core personnel and recommended occupations required to successfully conduct a single UAV operational mission include:

a. **DET CO.** Rank: Maj/LCol. This is the commander of the UAV detachment who disseminates tasks and orders..

b. **Mission Commander.** Rank: Capt/Maj. Plans, co-ordinates, and supervises UAV employment. All operations (national or international) including taskings/re-taskings/dynamic re-taskings, mission planning, surveillance conduct, flight profiles, weapon and counter measures employment, and safety are coordinated and controlled through the UAV Mission Commander.

c. **UAV Operator.** Rank: Lt/Capt. Operates and monitors the air vehicle in flight. Other duties include upload of mission profile to the AV; coordination of launch, recovery, and handover of the AV; and completion of all pre and post flight checklist items.

d. **Payload Operator.** Rank: MCpl – MWO. Operates the UAV sensor packages during flight. Other duties include testing of sensors prior to launch; extraction of combat information from the payload imagery; and identification of targets.

e. **Technicians.** Repairs and maintains the UAV system which includes the AV and GCS.

The three primary operators will be the UAV pilot, payload operator, and mission commander. The capabilities of these three operators must be represented within each MCE regardless of the platforms from which the UAV is being controlled. The exact number of operators required to fulfill each role will depend on the UAV (see Table 4 for the assumptions regarding crew composition for each UAV class). In addition to the aforementioned core personnel, a UAV detachment requires individuals to support capabilities such as launch and recovery, flight safety, and exploitation of imagery. Similarly, UAV operations in support of the navy require the establishment of a UAV Naval Liaison Element (NLE). This element could consist of the following personnel:

a. **NLE Commander.** Rank: Lt N. Responsible for NLE personnel. Direct liaison with UAV mission commander.

b. **Communications Operator(s).** Rank: AS – PO. Conduct communications between naval assets and UAV detachment.

c. **Communications Technician(s).** Rank: AS – PO. Establish and maintain communications and data-link with naval assets.

d. **Intelligence.** Rank: AS – PO. Naval subject matter expert. Conduct second line analysis of intelligence as well as record and prepare UAV Intelligence Summary (Intsum) packages.

4.7 Mission Description

4.7.1 General

The mission description presented in this report was developed using the mission phases or elements as documented in Section 4 of the Concept of Control of UAVs/UCAVs from Airborne Platforms Report by CMC Electronics as a baseline. The mission phases presented in the CMC document are common with minor modifications to all UAV/UCAV missions being controlled from any Mission Control Element land based, aboard ship or airborne. These mission phases have been tailored to accommodate the mission scenario presented in this report. The term "operator" used in the mission description is a generic term referring to the person performing the function or task unless otherwise specified. In addition, some of these phases may only be applicable to individual classes of UAVs.

4.7.2 Mission Preparation/Planning

When a number of mission control elements are tasked to participate in the UAV/UCAV mission the first decision command authorities must make is to designate one of them as the prime MCE. Although a number of factors will be taken into consideration, normally the MCE that can be expected to have the greatest degree of connectivity with all units participating in the mission including all levels of command authority will be designated as prime and will assume the lead in the mission planning process for the UAV portion of the mission. The mission planning process will be set in motion immediately upon the receipt of a tasking.

It is the task of the prime MCE to initiate contact with the LRE to determine the availability and configuration of UAV assets and then to subsequently coordinate the planning activities of all MCEs. The prime MCE will provide all MCEs with details of mission requirements and objectives, including sensor processing, communications, and data-link requirements, configuration and payload of UAVs and assigned AOO. Each MCE will then prepare their individual plans and crew briefings which include detailed intelligence and weather information.

4.7.3 Transit of the Airborne platform/Manning of MCE Positions

The functions and tasks discussed in this mission element are applicable to land and ship based MCEs as well as to the airborne platform in which case they are performed after take-off and during transit to the AOO. For land or ship based MCEs they would be performed when the operators man their positions. The first task at hand is for operators to ensure that all equipment, data-link and system checks are completed and that the Operator Control Workstation (OCW) is properly configured for the mission prior to arrival at the AOO and going on station.

Immediately upon manning the MCE the mission commander will establish communications with the LRE, mission command authorities, civil and military air traffic control facilities and all participating units.

4.7.4 Monitor and Manage Communications Infrastructure

The MCE team will monitor and manage communications continuously from the time they man their positions until the mission is terminated. The communication systems and devices to be monitored and managed include data-links, HF, VHF and UHF radios, and internal aircraft, ship or ground unit communication nets. Communications may be conducted by SATCOM or by LOS via Ground Air Transmit Receive (GATR) sites

The mission commander, vehicle operator, and payload operator may be on the same frequency or on different frequencies depending on the stage of the mission and the task to be performed. The UAV pilot will monitor Air/Ground/Air (AGA) radios including Guard and All Intercept Control Common (AICC) frequencies continuously. The MCE will use the internal communication nets to coordinate the activities of the team and to communicate with other areas of the aircraft, ship, or ground unit.

For additional information on the communications infrastructure, please refer to Section B.4.

4.7.5 Monitor and Manage Systems/Sensors

The monitoring of the OCW and peripheral equipment performance is a continuous function conducted by all MCE personnel. Each operator will monitor and manage the various unique displays associated with their position. The management of the various sensors will be discussed in detail under the heading of Conduct of the ISR Mission in Section 4.7.9 of this report.

4.7.6 Launch and Transit of the UAV/UCAV to the AOO

The launch of the UAV is transparent to the MCE operators as this function is handled by the operators at the Launch and Recovery Element. Control of the UAV will remain with the LRE until the UAV reaches its cruise altitude at which time it may be handed off to a civilian or military Air Traffic Control (ATC) facility, or to a MCE that is collocated with the LRE or to the MCE designated to control the UAV during the mission for transit. Normally transit to the AOO is conducted under approved flight plan. In order to facilitate radar tracking and identification the UAV will be assigned a discreet Selective Identification Feature (SIF)/Identification Friend-or-Foe (IFF) code to be transmitted during transit to the AOO.

4.7.7 Handover Control of UAV/UCAV

The procedures applied during the handover of control responsibility from one control agency to another are basically identical whether control is being transferred from the LRE or a civilian or military air traffic control facility to an airborne, shipboard, or ground based MCE or if it is being transferred between MCEs.

The agency controlling the UAV will establish contact with the agency assuming control responsibility. Normally contact will be by radio, however in the case of ground based agencies it may be by landline. Once contact between agencies has been established the controlling agency will provide a SIF/IFF point out of the UAVs position as well as flight profile to include heading, speed, altitude and SIF/IFF code or squawk. The receiving control agency may request a change in SIF/IFF squawk in order to facilitate identification of the UAV.

Due to the small radar cross section of many UAVs raw search radar contact and tracking is difficult to achieve therefore the use of SIF/IFF codes is the prime means used to make a positive identification (ID) and track UAVs. The UAV's SIF/IFF squawk will cause the automatic display of data at the UAV's position on the operator's radar display. The mission commander or UAV pilot will tag the UAV's radar contact with symbology that will display, at a minimum, a system generated identification number, direction vector as well as vehicle speed and altitude. The UAV's symbology will remain associated with the vehicle's track as long as the SIF/IFF code is being received or positive raw radar contact is maintained.

When the receiving agency is satisfied that they have a positive ID of the UAV they will advise the controlling agency that they are ready to assume control. Responsibility of UAV control and flight safety has now been transferred.

4.7.8 UAV/UCAV Flight Control

Flight control of the UAV is exercised by the UAV pilot under the direction of the mission commander. Control and navigation may be achieved by preprogramming routes and flight parameters into the UAV system before launch or by the UAV pilot transmitting command information such as heading, speed, and altitude to the UAV via data-link during flight. In either case it is the controlling MCE that is responsible for flight safety and air traffic separation.

Although there will be occasions when it will be essential that the UAV pilot intervene to dynamically direct or control the UAV's flight path and alter its flight profile in response to direction from the mission commander, a request from the sensor operator, or changes in the tactical or flight safety situation there will be very few instances when the UAV pilot will fly the UAV manually. The UAV pilot can seldom rely on the UAV's sensors to help in the flight control task, even if the sensor is locked onto a forward view since sensor optics seldom provides a wide enough Field Of View (FOV) for flying operations.

The UAV pilot will maneuver the vehicle in patterns that will optimize the contribution of the UAV's sensors to the mission by inserting a series of waypoints or if required by manually vectoring the vehicle in response to a specific event such as confliction with other air traffic. During the conduct of the mission the UAV pilot will continuously monitor radar displays in addition to information being received from the UAV's forward viewing sensor.

In the event of an emergency involving a UAV the controlling MCE will immediately advise the air traffic control agency responsible for the AOO as well as all applicable military authorities. Most emergencies will involve loss of control of the vehicle or loss of contact. The UAV pilot will continue to monitor all displays and transmit data-link commands in an effort to regain contact and control of the UAV. In the event that contact can not be established and control not regained then the mission commander may, in the interest of flight safety, initiate destruction of the vehicle.

4.7.9 Conduct of ISR Mission

4.7.9.1 General

In the roles and missions assigned to the Canadian Forces in peacetime the function of UAVs is to provide ISR. Intelligence gathering is the systematic acquisition of strategic information about a specific target of interest through the use of photography and/or sensors, including infrared, lasers, electro-optics, and radar. Surveillance refers to the systematic observation of an assigned area while reconnaissance is the systematic acquisition of tactical

information about the activities of a target of interest. Although by definition these are three separate tasks there is considerable overlap in how these tasks are accomplished by UAVs and in the information that is acquired by their execution; therefore, they have been integrated into a single mission: ISR.

4.7.9.2 Management of Sensor Information

The MCE will filter, sort, prioritize, retransmit, and store information being received from EO, IR, and SAR sensors. The objective of the mission is to process then communicate the still and moving imagery to command authorities such as MARLANT as well as to other assets participating in the mission. The timeliness and speed of transfer are of vital importance to mission success.

The payload operator will manage the onboard sensors and process the sensor imagery as directed by the mission commander. The mission commander will decide, based on the tactical situation and mission objectives, what data has to be transmitted to command authorities and what data can be archived for future analysis. In some cases all information must be streamed from the MCE to command.

4.7.9.3 Monitoring and Management of Displays

The mission commander and payload operator have the capability of monitoring EO, IR and SAR information displayed at their OCW. The UAV pilot will concentrate on monitoring EO imagery and a radar display in performance of flight control tasks. The operators will monitor the imagery being provided by UAVs under their control as well as periodically view data being received from UAVs that are under the control of other participating MCEs.

4.7.10 Handover of UAV/UCAV for Transit and Recovery

When the mission has been completed the procedures to be applied for the handover of control responsibility of the UAV for the purpose of transit to home base and subsequent recovery are virtually identical to the procedures described at Section 4.7.6. Control may be transferred from the MCE performing the mission to a civilian or military air traffic control facility or to an MCE that is designated to handle transit control to and from the UAV homebase.

As was the case in the launch of the UAV, recovery is transparent to the MCE as these activities are handled exclusively by the LRE.

4.7.11 Post-Mission Activities

The MCE team will complete all post mission documentation such as mission reports and logs as soon as possible after mission completion. Data reduction from the UAV's system will be conducted by the LRE after vehicle recovery.

The MCE mission commander of the prime MCE will conduct a "Hotwash" debrief with other MCEs and the LRE as soon as possible after the mission is completed. In preparation for the complete debrief that will be convened by the tasking authority, archived imagery will be analyzed and edited by intelligence staff.

5 Mission Scenario

5.1 General

The primary product associated with this effort is a Mission Scenario. The primary objective in developing a mission scenario is to provide a baseline for future analysis activities and experimentation. In this context, the experimental landscape involves the command and control of UAV/UCAV devices to evaluate the impact of various Intelligent Adaptive Interface constructs. To support program requirements as they evolved over the period of conduct of this program, it was necessary to iterate the scenario from its original release to a final version, as captured in this document.

The original mission scenario for DRDC (attached as Appendix C) was developed to provide a framework to illustrate the elements described in the mission analysis and to identify the unique mission-critical operational activities performed by the UAV MCE team on an airborne platform. Although the number of UAVs that the MCE can be expected to manage simultaneously is unknown at present, the original scenario was designed to expose the airborne UAV MCE team to the maximum workload that could realistically be expected.

Additional requirements were identified by the CFEC office during the scenario review process, requiring an iteration of the document. To satisfy CFEC's objectives, a next generation mission scenario has been developed based primarily upon discussions with CFEC personnel [Reference 30]. This final scenario is presented in the following sections.

Both the original and final scenarios are based on the same type of mission (CD OP) with a similar chain of events. In comparison with the original scenario, the final scenario incorporates the following changes:

a. A suite of UAVs (MALE, Tactical, and Mini UAVs) are employed to complete the mission as opposed to multiple MALE UAVs.

b. Flight control of the MALE UAV remains with the 4 ADR MCE throughout the duration of the mission. To that end, the airborne MCE has payload control of the MALE UAV but never assumes flight control of this asset.

c. Flight and payload control of the Mini UAVs is passed back and forth between airborne and shipborne MCEs.

d. The CP-140 launches and controls a Mini UAV in support of the mission.

e. Operations are conducted in a geographical location consistent with the upcoming ALIX exercise (i.e. off the coast of Newfoundland vice Nova Scotia).

In addition to the similarities in the scenarios events, the documentation contains redundant sections as these two scenarios are treated as separate entities that can be utilized independently from one another.

5.2 Mission Overview

The mission chosen for the scenario is a counter drug operation conducted in conjunction with a routine fisheries surveillance patrol as this represents a realistic domestic operations tasking received by the Canadian Forces in peacetime. In fact, the Canadian Forces conducts several counter-drug operations, in support of RCMP operations, every year on both East and West coasts.

The mission for the UAV in the conduct of a CD OP or FISHPAT is an Intelligence gathering, Surveillance and Reconnaissance mission. ISR are unique tasks, yet there is considerable overlap in how these three tasks are accomplished by UAVs and in the information that is acquired by their execution. As a result, the three tasks will be integrated into a single task for the purposes of this scenario.

The operational level commanders for domestic operations, including CD OPs and support to other government departments are: Commander MARLANT, Commander MARPAC, Land Force Area (LFA) Commanders, Commander 1 CAD, and Commander Canadian Forces Northern Area HQ (CFNAHQ). Operational level commanders are responsible directly to the CDS.

CF counter drug operations are governed by a Memorandum of Understanding (MOU) between the Minister of National Defence (MND) and Solicitor General that specifies the support the CF may supply. Support under the MOU is limited to surveillance, intelligence sharing and interdiction. Any other support must be the subject of a separate request from the Solicitor General to the MND. CF counter drug operations are coordinated at the National Defence Headquarters (NDHQ) level by the Chief of Staff Joint Operations (COS J3), who maintains a liaison cell (CFLO RCMP) with the RCMP.

5.3 Assumptions

The assumptions regarding factors such as the UAV system employed, manning, and participating units are detailed in Table 4.

Table 4: Scenario Assumptions

Category	Assumptions
UAV System	• All MALE UAVs will be Predator type with a payload of EO/IR and SAR sensors. • All Tactical UAVs will be Eagle Eye type with a payload of EO/IR and SAR sensors. • All Mini UAVs will be Seascan type with an EO camera. • The baseline level of autonomy for each UAV system will be consistent with the Predator, Eagle Eye, and Seascan. Future evolutions of the systems as defined through experimentation will subsequently increase the UAV's autonomy level. • The airborne MCE will be onboard a CP-140 Aurora. • The ship based MCEs will be in the operations rooms onboard a Canadian Patrol Frigate (CPF) and a Maritime Coastal Defence Vessel (MCDV). • 4 ADR LRE has a co-located MCE. Communications bandwidth will be provided as required by the UAV and controlling agency.

Table 4: Scenario Assumptions

Category	Assumptions
UAV System (cont'd)	• The UAV remains in the positive control, including both flight and sensor operation, of the controlling agency at all times. • UAVs will be employed in a role that is functionally similar to ALIX using technology that is forecast to be available in 2008.
Manning	• All MCEs have adequate manning to permit 24hrs operations for at least 3 days. • MALE UAV requires 4 operators: Mission Commander, UAV pilot, and two payload operators. • Tactical UAV requires 2 operators: UAV pilot and payload operator. • Mini UAV requires 1 operator to both fly the AV and control the payload. • Based on current practice, each MCE will be manned with a qualified pilot who will be dedicated to the flight control of UAVs. • CP-140 Aurora manning will be from the current mission crew augmented by a qualified pilot as the AV operator. The Tactical Navigator (TACNAV) will serve as mission commander, and a Non-Acoustic Sensor Operator (NASO) as payload operator. • Ship based manning for the CPF will be from the operations room team augmented by a qualified pilot as the UAV pilot. The Operations Room Officer (ORO) will serve as mission commander, and the Shipborne Air Controller (SAC) as payload operator. • Ship based manning for the MCDV will consist of a qualified pilot acting as the UAV pilot controlling both the AV and sensors. • Land based MCE manning consists of a combat arms officer as mission commander, a combat arms Non Commissioned Member (NCM) as payload operator and a qualified pilot as AV operator.
Participating Units	• CP-140 Aurora • Canadian Patrol Frigate • Maritime Coastal Defence Vessel • CH-149 Cormorant (x2) • RCMP SERT (x2)
General	• Weather is Visual Flight Rules (VFR), however the ceiling will drop as the mission progresses. • The Sea King Helicopter is not onboard the HMCS Montreal; therefore, 4 VTUAVs are on board the CPF. • Air traffic control will provide altitude reservations for UAVs

Table 4: Scenario Assumptions

Category	Assumptions
	transiting to and from the AOO and have given authority to CF MCEs to provide control in the AOO. • The AOO is a block of airspace 200nm by 200nm south of the Grand Banks.

5.4 Situation

5.4.1 General

The time is 0100 hours 21 Mar 04. The situation at the beginning of the scenario is that 3 days ago the RCMP through the CFLO RCMP generated a request for CF support in a CD OP to be conducted in the next 12 to 24 hours. In response to this request NDHQ has initiated a CD OP code name "Helping Hand 2004-01". The goal of a CD OP is to detect, track, and intercept ships and aircraft in order to prevent the delivery of narcotics into Canada.

NDHQ appointed Commander MARLANT to act as Task Force Commander Atlantic (TFCLANT). Maritime Air Commander Atlantic (MAC-A) is appointed as the Air Component Commander Atlantic, Commander Atlantic Fleet (LANTFLT) is designated as the Maritime Component Commander Atlantic and Commander Land Forces Atlantic Area is designated the Land Force Component Commander.

The mission will be coordinated from the MARLANT Headquarters at Canadian Forces Base (CFB) Halifax.

The RCMP has deployed two Special Emergency Response Teams (SERTs). Team 1 will take up ground positions in the vicinity of Burin, Newfoundland before 0800 hours. Team 2 has been taken aboard HMCS Winnipeg which has been tasked to support the mission.

The Ship Of Interest (SOI) is presently being tracked by US Customs aircraft working with a US Coast Guard vessel.

Concurrent with this activity HMCS Montreal is conducting a FISHPAT approximately 180nm south of Burin. Montreal has 4 VTUAVs onboard. HMCS Kingston is located 150nm southwest of Burin Newfoundland conducting a coastal patrol. There are 2 Mini UAVs on board this MCDV.

Alpha 01 is airborne north of Gander on exercise with payload control of the MALE UAV and 6hrs of mission time remaining.

HMCS Kingston is conducting a coastal patrol within the Cabot Strait between Cape Breton and Newfoundland. There are 3 Mini UAVs on board this MCDV.

All mission planning has been completed and units are preparing to deploy.

5.5 Factors Effecting the Mission

5.5.1 Participating Forces

The CF operations are conducted in concert with a number of government departments and organizations including the Canadian Security Intelligence Service (CSIS), RCMP, the

Communications Security Establishment (CSE) and Canadian Coast Guard. In addition, the CF and RCMP will work closely with US Customs and intelligence organizations.

In addition to the 2 SERT teams, the RCMP will assign a member to MARLANT Headquarters.

The CF assets listed below have been tasked by TFCLANT through the appropriate operational level command headquarters to participate in "Helping Hand 2004-01". Air assets will be tasked via Air Tasking Orders or the "Rain Form" system.

f. 4 ADR, Royal Canadian Artillery UAV Detachment located at CFB Greenwood provides the LRE and a MCE to facilitate control of MALE UAVs during transit to and from the AOO;

g. Aurora flying north east of Gander on exercise with payload control of the MALE UAV and 6hrs of mission time remaining. Flight control of the MALE UAV is performed by 4 ADR. Aurora is equipped with Mini UAVs that can be launched while airborne;.

h. 9 Wing located at Gander, Newfoundland provides two Cormorants for the transport of RCMP SERTs from St. Johns to both Durbin and the HMCS Montreal;

i. HMCS Kingston is conducting a coastal patrol between Cape Breton and Newfoundland. There are 2 Mini UAVs on board this MCDV.

j. CP-140 Aurora on 8 hour alert at 14 Wing CFB Greenwood has been brought up 3 hour alert. An additional CP-140 has been placed on 8 hour alert and will be brought up to 3 hour alert if the first Aurora is scrambled. All Auroras will be manned with a UAV MCE; and

k. HMCS Montreal is conducting a FISHPAT approximately 180nm southeast of the Grand Banks. There are 4 VTUAVs on board the HMCS Montreal since the CPF was deployed without a Sea King helicopter.

During the conduct of the mission, re-tasking direction will be issued by either written or verbal format from the designated command authority in order to change the mission or location of the UAV while it is airborne. Re-Tasking only occurs when the new mission is assigned a higher priority than the one undertaken in the initial tasking. Dynamic Re-Tasking is reserved for the UAV mission commander to immediately react to a changing situation as detected by the UAV during the course of either the initial tasking or re-tasking.

5.5.2 Manning

All MCEs have sufficient personnel to facilitate 24hr manning for the duration of the mission.

5.5.3 Enemy Forces

This is a peacetime mission with peacetime Rules Of Engagement (ROEs) in effect; therefore, there are no actual "Enemy Forces" in the purest sense of the term. Vessels that are carrying contraband or are in violation of fishery regulations are the "enemy" in this scenario.

The RCMP have been advised that a SOI, the Motor Vessel (MV) Blade Runner, that both the RCMP and US authorities have been interested in for an extended period of time is presently 475nm south of Burin, Newfoundland heading north at 19 kts. The vessel is being

shadowed by a US Customs aircraft. It is believed that the MV Blade Runner is a mother ship carrying a large quantity of contraband to be off loaded to a smaller vessel for transportation ashore.

RCMP intelligence has confirmed that the fishing vessel "John D" currently tied along side in Burin, Newfoundland is waiting to make contact with the MV Blade Runner for off loading of the contraband.

Although there are approximately 800 fishing vessels operating in the East Coast fishing zone, HMCS Montreal has not observed any infractions of fishery regulations.

5.5.4 Climate/Weather

This area frequently experiences extensive areas of fog and low cloud cover accompanied by precipitation at this time of year. These conditions would severely limit the use of EO and IR sensors.

The present weather is Ceiling and Visibility OK (CAVOK) throughout the AOO. However, the weather is forecasted to deteriorate throughout the mission.

5.5.5 Time and Space Constraints

The mission may be conducted at great distances from the home bases of the tasked assets; therefore, the ability to have theses assets available where and when they are needed is heavily dependant on timely and accurate intelligence information. Extended transit times are a major factor to be considered in mission planning.

Timely and accurate intelligence is also a major factor in determining the actual surveillance time required. Without high quality intelligence surveillance activities may have to be conducted for several days leading up to contact with the Targets Of Interest (TOI).

For this CD OP the positioning of assets is a major challenge.

5.6 Chronological Sequence of Mission Events

All times are Eastern Standard.

21 Mar 04

0200hr MARLANT headquarters are advised by Canadian North American Aerospace Defence Command (NORAD) Region that the US Customs aircraft currently shadowing the SOI has 1 hour of mission time remaining and the planned replacement aircraft is a ground abort with no replacement available. The SOI is 275nm southeast of Burin, Newfoundland and not 475nm as first reported. This means that the SOI is 10 hrs closer than was expected. See Figure 14.

0205hr MARLANT headquarters issues re-tasking order to Alpha 51 (airborne CP-140) to the CD OP. A second CP-140 is given an airborne order for 0500hrs.

4 ADR MCE vectors Viper 01 (MALE UAV) into position to detect the SOI.

0206hr Alpha 51 heads south to a new orbit point.

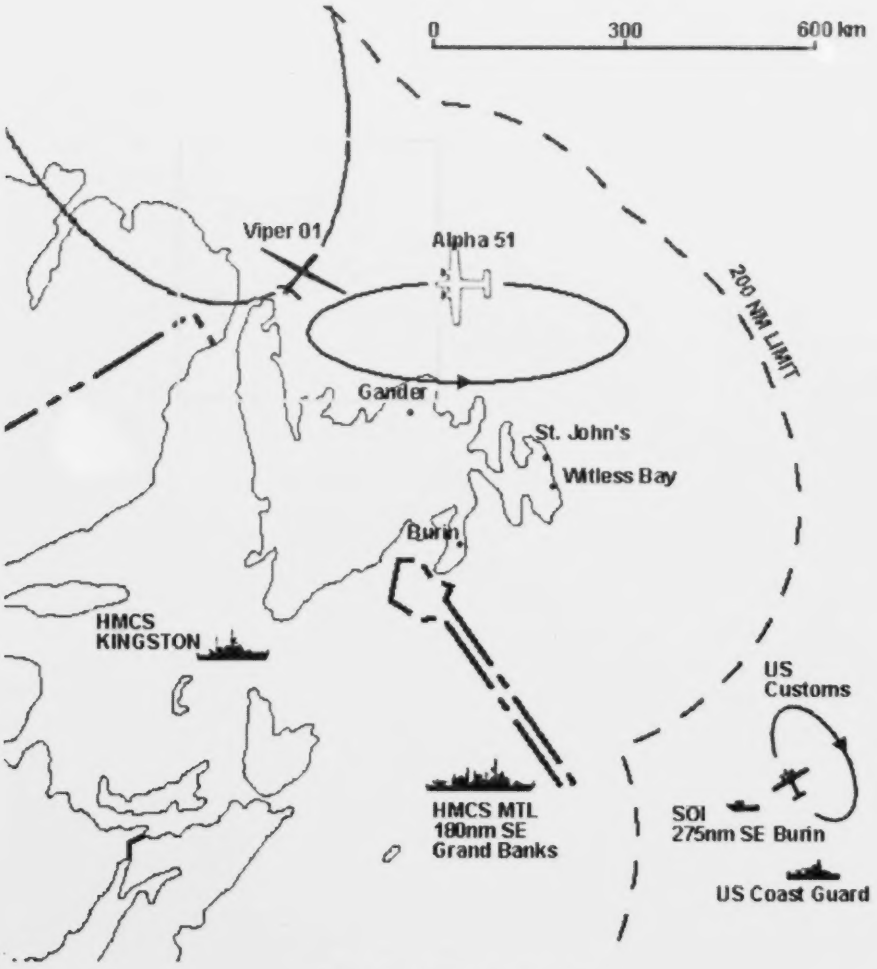

Figure 14: 0100 to 0200 Hrs

0207hr MARLANT headquarters request authority from NDHQ to re-task HMCS Kingston from its current coastal patrol mission and HMCS Montreal from its current FISHPAT mission to the CD OP.

0208hr MARLANT receives authority to re-task both ships to the CD OP.

0210hr HMCS Montreal is appointed by MARLANT as Officer in Tactical Command (OTC) and is directed to establish communications with the US Customs aircraft. The MCE Commander on HMCS Montreal is briefed on the mission by MARLANT.

0215hr Communications are established between US Customs aircraft and HMCS Montreal.

0216hr The HMCS Montreal has a contact on its RMP 80nm southeast heading north. This contact is confirmed by US Customs Aircraft to be the SOI.

0231hr The MCE aboard the HMCS Montreal assumes responsibility for shadowing the SOI from the US Customs aircraft. The payload operator onboard Alpha 51 has taken the first SAR shot to detect the SOI. The UAV pilot at 4 ADR MCE is vectoring Viper 01 at Flight Level (FL) 150 to optimize sensor performance.

4ADR MCE UAV pilot transmits a series of waypoints to Viper 01 that establishes a pattern that allows the payload operator to keep the EO and IR sensors pointed at the SOI.

HMCS Montreal and MARLANT headquarters are receiving SAR imagery. MARLANT headquarters to analyse SAR imagery for classification purposes.

0232hr Viper 01 has detected the SOI is 220nm southeast of Burin still heading northwest at 19kts.

0233hr Based on previous intelligence from the RCMP, MARLANT headquarters is able to match the SOI profile to the profile of a drug vessel.

0235hr The US customs aircraft has gone off station.

0315hr Weather deteriorates to conditions that make EO and IR tracking from the MALE UAV no longer reliable. The Aurora continues to receive SAR imagery from the MALE UAV that captures and tracks the SOI but only intermittently with approximately 50% confidence due to the inclement weather.

0320hr Alpha 51 is in an orbit 100nm south of St John's. See Figure 15.

0321hr MARLANT headquarters tasks HMCS Montreal to launch VTUAV to provide positive identification of the SOI.

0325hr HMCS Montreal launches Bingo 61 to fly out at 5000ft ASL and ID the SOI.

0350hr Bingo 61 has contact EO/IR on the SOI...Bingo 61 provides positive identification that the SOI is the Blade Runner and commences tracking and videotaping.

0400hr Alpha 51 and Viper 01 continue to shadow the SOI from a covert position, maintaining SAR tracking and reporting regularly on the SOI's progress and activities. EO/IR tracking is becoming increasingly difficult.

0430hr Alpha 51 remains on station with payload control of Viper 01.

0435hr Viper 01 remains on station under 4ADR MCE flight control providing SAR shots; however, it has lost EO/IR contact on the SOI due to the deteriorating weather conditions.

0450hr Bingo 61 continues videotaping the SOI and gather evidence for future prosecution.

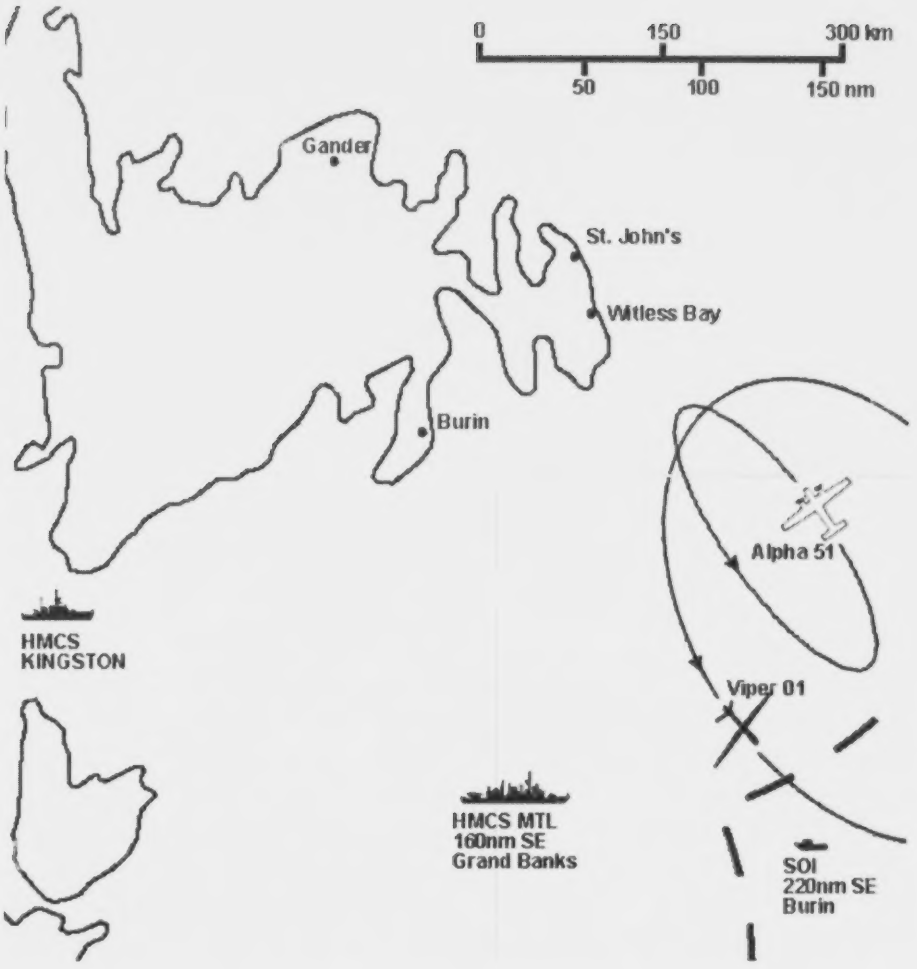

Figure 15: 0320 Hrs

0500hr The SOI is now 170nm south of Burin.

HMCS Kingston is 120nm southwest of Burin. See Figure 16.

0506hr Alpha 52 is airborne from Greenwood heading northwest at FL 250 and 205 KIAS. Once on station, Alpha 52 will assume payload control of Viper 01.

0515 Alpha 52 MCE conducts equipment, data-link, and communications checks while in transit to the AOO. Alpha 52 mission commander contacts Alpha 51 and receives mission updates. Alpha 51 reports having payload control of Viper 01 and tracking the SOI. Alpha 52 establishes radio contact with HMCS Montreal.

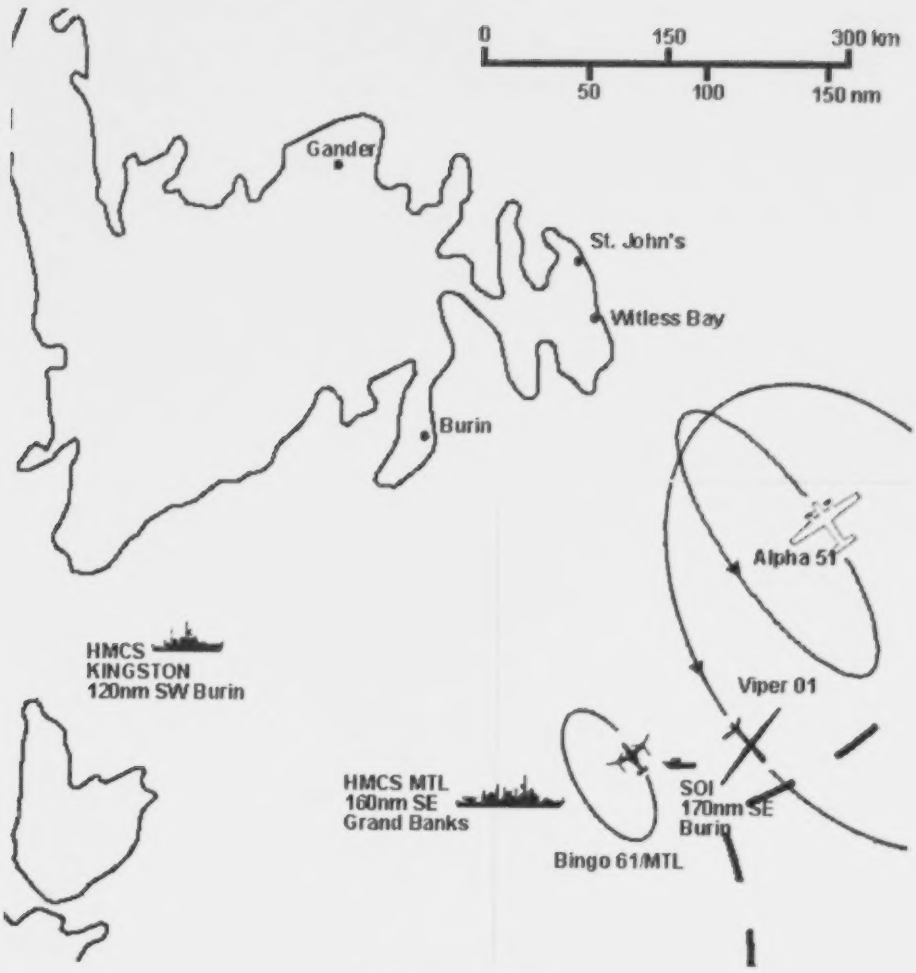

Figure 16: 0500 Hrs

0557hr Cormorant Charlie 81 is airborne from St John's to HMCS Montreal with a SERT team.

0650hr Cormorant Charlie 82 is airborne from St John's to Burin with a SERT team.

0700hr HMCS Kingston is 120nm southwest of Burin steaming at 20kts. See Figure 17.

0701hr The SOI is 130nm south of Burin being tracked by Bingo 61 with the Montreal maintaining its covert position.

0702hr HMCS Montreal launches Bingo 62 to replace Bingo 61.

0705hr Charlie 81 arrives in Burin with the RCMP SERT.

0730hr RCMP SERT 1 is in position in the vicinity of Burin and have established radio contact via a Transportable Satellite Communications System (TSCS).

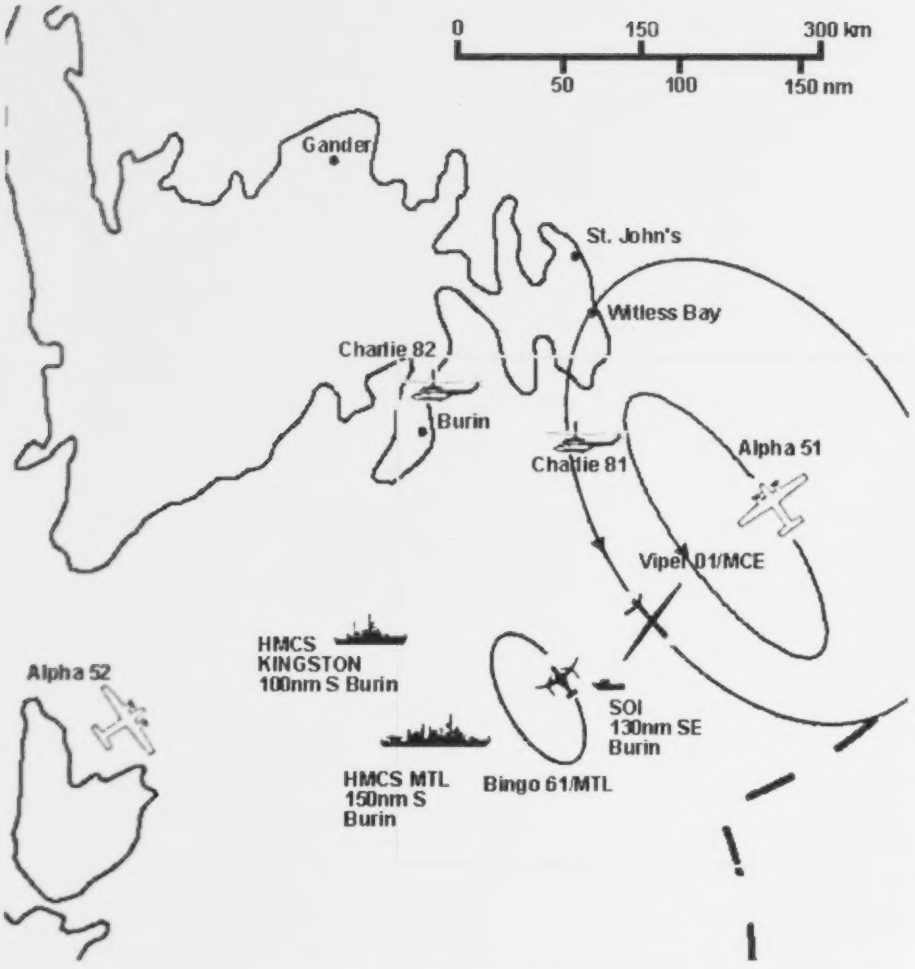

Figure 17: 0700 Hrs

0740hr Bingo 62 has EO/IR contact on the SOI. Bingo 61 is RTB to HMCS Montreal.

Viper 01 is continually taking SAR shots of the SOI and the Burin area.

0750hr Alpha 52 arrives on station and assumes payload control of Viper 01.

0800hr The RCMP SERT reports that the John D is still in harbor but appears to be getting ready to leave.

0805hr Bingo 61 is recovered by HMCS Montreal.

0810hr MARLANT directs Alpha 52 to launch a mini UAV to provide surveillance of the Burin area in anticipation of the John D leaving the harbor.

0811hr Alpha 52 launches Mike 91 to begin EO surveillance.

0812hr Alpha 52 hands over payload control of Viper 01 to HMCS Montreal since the OTC is on-board the CPF.

0815hr Charlie 81 puts the SERT onboard HMCS Montreal.

0830hr Mike 91 commences EO surveillance of the Burin area under the flight and sensor control of Alpha 52.

0900hr The SOI is 100nm south of Burin being tracked by Viper 01. See Figure 18.

0916hr 4ADR MCE UAV pilot transmits a number of way points to vector Viper 01 to a point 30nm outside of Burin harbor.

1000hr The payload operator of Viper 01 is taking SAR shots of the SOI as well as monitoring activity at the harbor approaches.

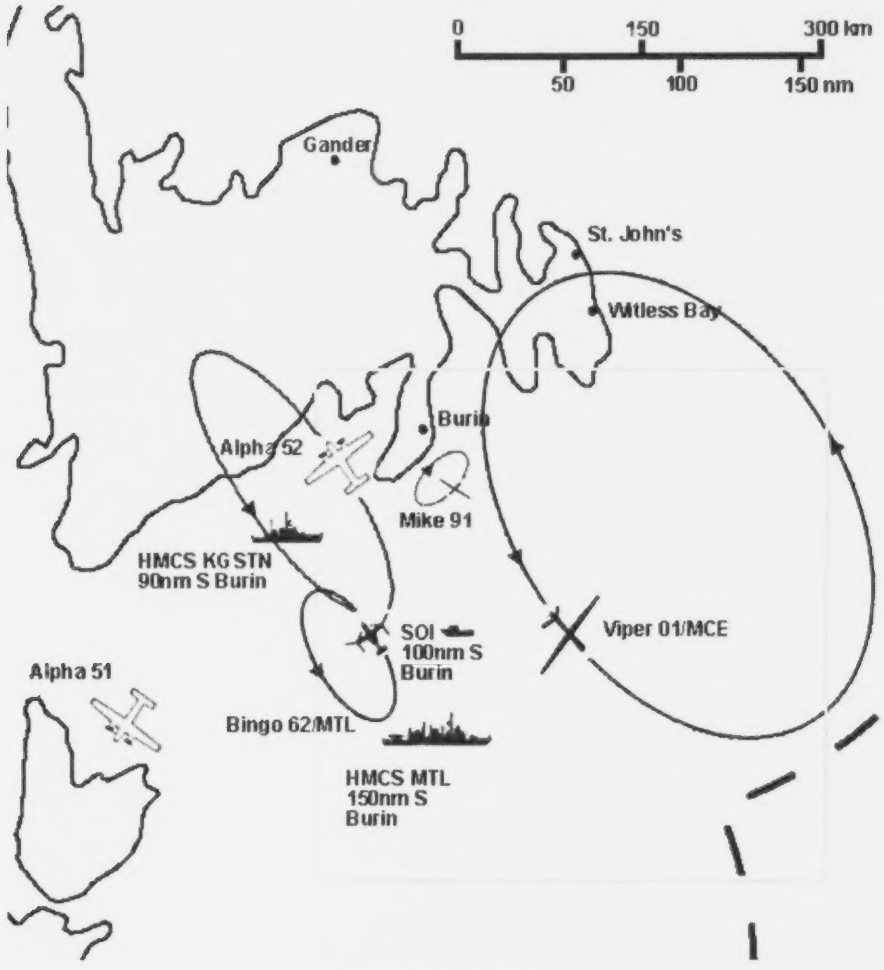

Figure 18: 0900 Hrs

1100hr HMCS Kingston reports to be on station at a point 60nm southwest of Burin beyond line of sight of the SOI.

The SOI is 70nm south of Burin being tracked by Bingo 62. HMCS Montreal remains in a covert position southwest of the SOI.

1110hr HMCS Kingston launches Mike 92 to replace Mike 91 as it will soon reach its endurance limit.

1115hr Alpha 52 assumes LOS control of Mike 92 while the UAV is in transit to the AOO. Mike 92 will fly from programmed waypoint to waypoint from its present position to the AOO. The UAV pilot is monitoring the progress of Mike 92 and the payload operator is running the checklist for initiating the operation of the UAV's sensor and from this point on will monitor and manage their performance.

1135hr HMCS Montreal launches Bingo 63 to take over tracking of the SOI from Bingo 62 which will soon reach its endurance limit.

1140hr. Mike 92 is on station and begins to monitor activities in the Burin area in anticipation of the John D leaving the harbour. HMCS Montreal is receiving EO imagery from Mike 92

Alpha 52 vectors Mike 91 to a point 100nm southwest of Burin where it crashes.

1159hr Bingo 63 is on station. The payload operator on board the Montreal correlates EO and IR information being received from Bingo 63 with that received from Bingo 62 and determines that Bingo 63 has positive contact on the SOI.

1200hr The SOI is 60nm south of Burin and is now being tracked by Bingo 63 as well as shadowed by HMCS Montreal. Bingo 62 is RTB to HMCS Montreal.

HMCS Kingston is maintaining a covert position 60nm southwest of Burin. See Figure 19.

1205hr The RCMP SERT team reports that the John D is underway from Burin

1210hr Viper 01 payload control is handed over to the OTC onboard Montreal.

1230hr Alpha 52 passes control of Mike 92 to HMCS Montreal and remains on station to serve as a radio relay between Mike 92 and the Montreal.

1235hr HMCS Montreal recovers Bingo 62.

1335hr Mike 92 has an EO contact leaving Burin harbor. The Viper 01 payload operator takes a series of SAR shots of the area.

1345hr EO images from Mike 92 confirm that the contact leaving Burin is the John D. The contact is heading southwest. Viper 01 is vectored to a different orbit in order to provide improved SAR shots of the Burin area and the SOI

1346hr SITREPs are continually being sent to MARLANT by HMCS Montreal.

1400hr Bingo 63 is maintaining EO/IR tracking on the SOI. Mike 92 is maintaining EO contact on the John D. Viper 01 is continually taking SAR shots of both the SOI and John D. At the present rate of closure between the SOI and the John D the rendezvous should take place at about 1600hrs at a point 30nm south of Burin.

1430hr HMCS Kingston launches Mike 93 to replace Mike 92.

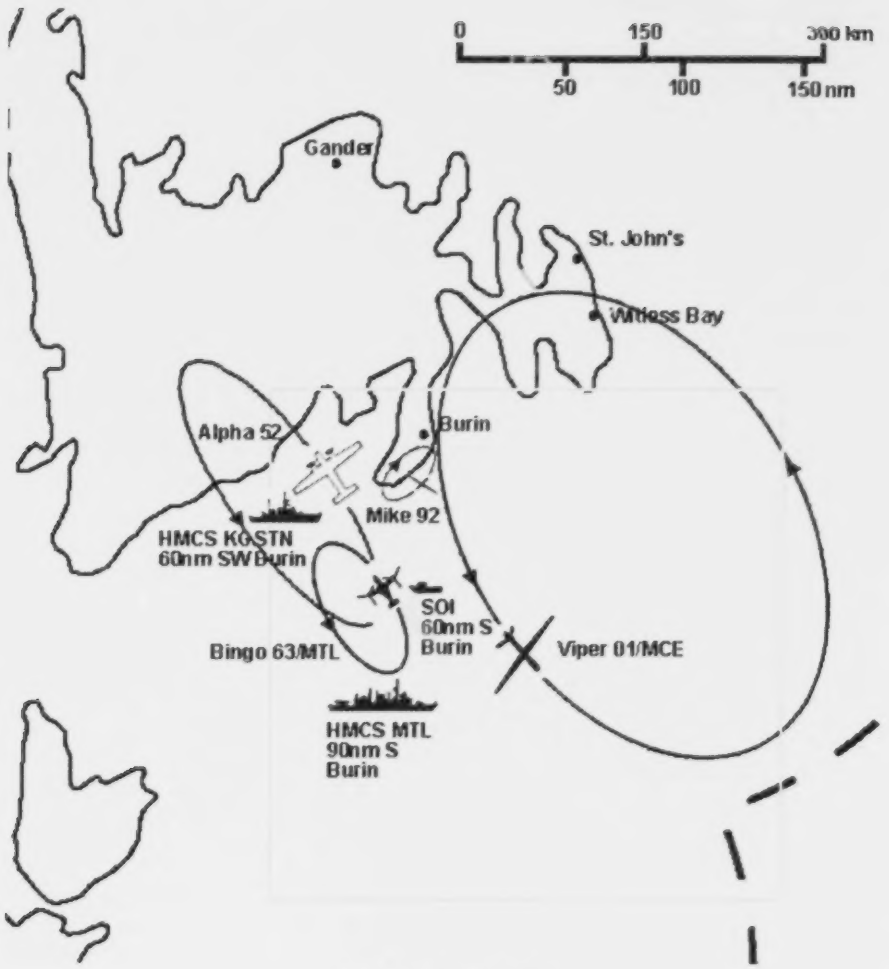

Figure 19: 1200 Hrs

1432hr HMCS Montreal launches Bingo 64 to replace Bingo 63.

1440hr Alpha 52 assumes LOS control of Mike 93 while the UAV is in transit to the AOO.

1500hr Mike 93 is on station. Alpha 52 passes control of Mike 93 to HMCS Montreal and remains on station to serve as a radio relay between Mike 93 and the Montreal.

The payload operator on board the Montreal correlates EO information being received from Mike 93 with that received from Mike 92 and determines that Mike 93 has positive contact on the John D.

1502hr Mike 92 control is handed from HMCS Montreal to Alpha 52 for RTB to HMCS Kingston.

1505hr Bingo 64 is on station. The payload operator on board the Montreal correlates EO and IR information being received from Bingo 64 with that received from Bingo 63 and determines that Bingo 64 has positive contact on the SOI. Bingo 63 is RTB to HMCS Montreal. .

1525hr Control of Mike 92 is passed from Alpha 52 to HMCS Kingston for recovery.

1530hr The SOI is being tracked by Bingo 64 40nm south of Burin still heading north. The John D. is being tracked by Mike 93 25nm south of Burin heading south.. See Figure 20.

1532hr HMCS Kingston recovers Mike 92.

1535hr HMCS Montreal recovers Bingo 63.

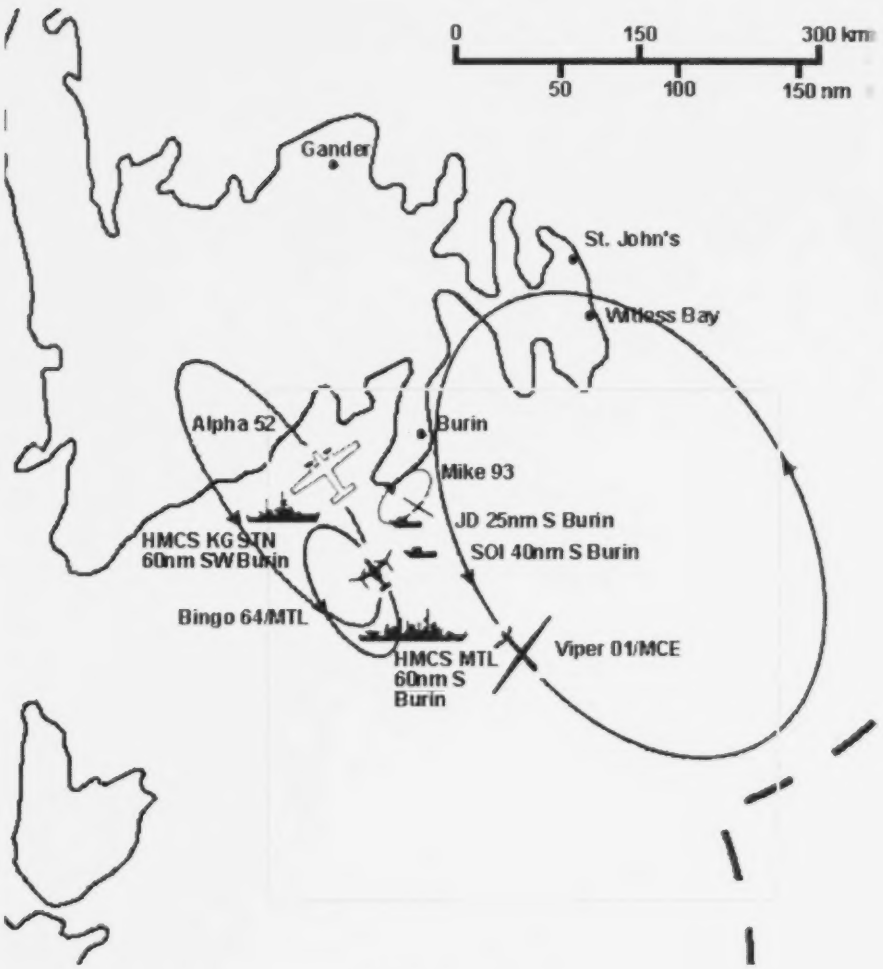

Figure 20: 1530 Hrs

1558hr In a SITREP to MARLANT HMCS Montreal reports that the John D is circling at a point 10nm south of Burin and the SOI is heading toward that position.

1610hr The John D is now heading south and appears to be on a track directly to the SOI which is 20nm south. This activity is being observed by the sensors aboard Bingo 64 and Mike 93. Viper 01 is taking numerous SAR shots.

1620hr The John D is along side of the SOI and both ships are dead in the water at a point 15nm south of Burin drifting north. This activity is being observed by the sensors aboard Bingo 64 and Mike 93. Viper 01 is taking numerous SAR shots.

1630hr Both Bingo 64 and Mike 93 observe cargo being off loaded from the SOI to the John D. See Figure 21.

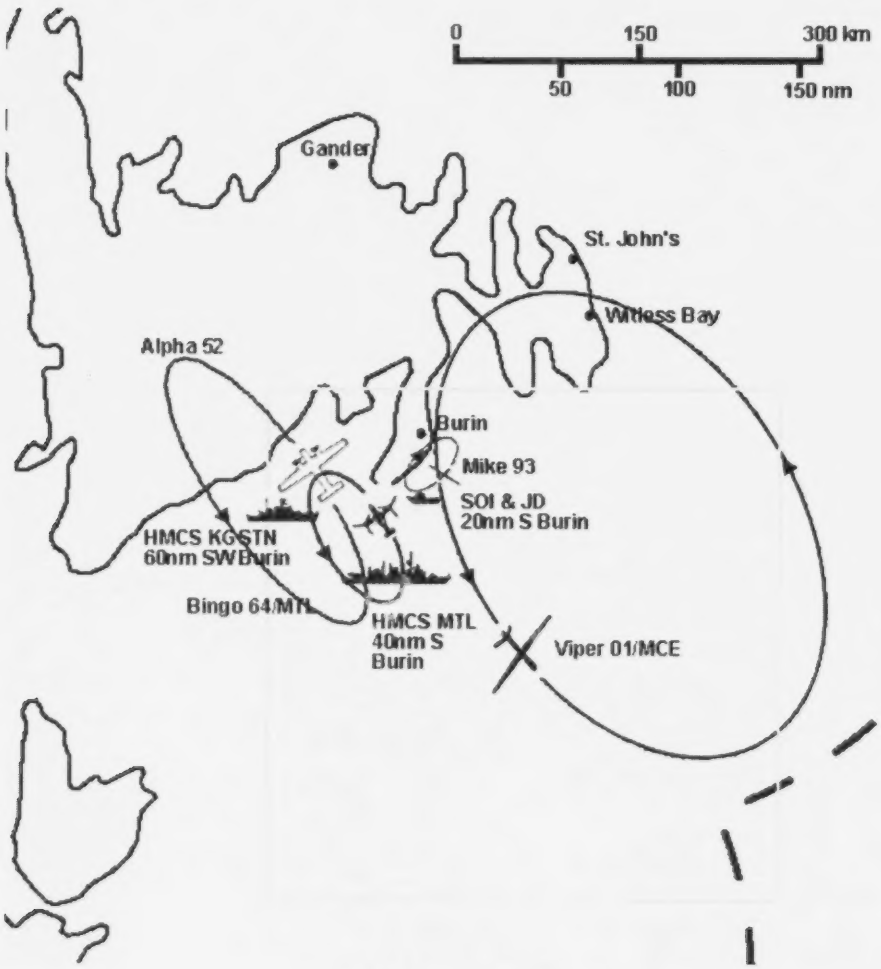

Figure 21: 1630 Hrs

1650hr The off-loading has been completed. The John D turns north and heads to Burin. The SOI turns south.

All activity is being observed by the sensors aboard Bingo 64 and Mike 93. Viper 01 is taking numerous SAR shots. All data is being down linked to MARLANT and the OTC onboard HMCS Montreal is providing MARLANT with voice updates.

Alpha 52 is still on station providing radio relay between all units as required.

The RCMP SERT has been monitoring all radio traffic and is aware that the John D is their target and it is heading back to Burin.

1652hr Alpha 52 is providing the RCMP SERT with constant voice updates.

1655hr SOI stops 20nm south of Burin and puts a small high speed craft over the side.

The high speed craft heads northeast towards Witless Bay.

All activity is being observed by the sensors aboard Bingo 64 and Mike 93. Viper 01 is taking numerous SAR shots. All data is being down linked to MARLANT and the OTC onboard HMCS Montreal is providing MARLANT with voice updates.

1710hr Charlie 81 takes 4 members of the SERT to Whitless Bay

1740hr The John D enters Burin harbor.

1745hr The high speed craft is approaching Whitless Bay.

All activity is being observed by the sensors aboard Bingo 64 and Mike 93. Viper 01 is taking numerous SAR shots. All data is being down linked to MARLANT and the OTC onboard HMCS Montreal is providing MARLANT with voice updates.

1750hr The HMCS Montreal gives up her covert position to intercept the SOI.

1810hr The SOI has stopped after being hailed by the HMCS Montreal and the RCMP SERT is preparing to board.

1815hr The John D is coming along side in Burin and the RCMP SERT are preparing to move into position. This activity is being observed by Mike 93.

1830hr The high speed craft enters Whitless Bay. Viper 01 is taking SAR shots.

1840hr HMCS Montreal reports that the RCMP SERT is onboard the SOI, the Blade Runner. The SERT will remain onboard and the HMCS Montreal will escort the ship to St John's. The ships are heading northeast to St John's at 17kts.

1900hr The Burin and Whitless Bay end games are complete. MARLANT directs HMCS Montreal to terminate CD OP Helping Hand 2004-01.

1905hr 4 ADR advises ATC and 14 Wing operations that they have Viper 01 under their control for immediate RTB Greenwood.

1910hr Control of Mike 93 is assumed by Alpha 52 for RTB HMCS Kingston.

1925hr Control of Mike 93 passed from Alpha 52 to HMCS Kingston for recovery. Alpha 52 is off station for RTB Greenwood..

1925hr HMCS Montreal recovers Bingo 64.

1930hr HMCS Kingston recovers Mike 93.

2250hr 14 Wing Ops reports Alpha 52 down at 2249hrs.

2300hr MARLANT stands down and post mission activities commence.

5.7 Timeline of Major Scenario Events for IAI Testing

As previously mentioned, the intended use of the mission scenario is as a baseline facility for IAI experimentation. The UAV structure provides the testbed for which the impact of IAI constructs upon UAV operations can be evaluated. To assist this effort, Figure 22 illustrates the mission scenario timeline annotated with major events. The timeline has also been divided into seven 'chunks' whereby each chunk is deemed conducive for IAI experimentation. Selection of the chunks was based on identifying periods within the scenario that may exhibit excessive operator workload due to factors such as simultaneous receipt of sensor data from multiple UAVs, dynamic re-tasking of UAVs, transfer of UAV control between agencies, and/or concurrent control of multiple UAVs. The seven chunks considered for IAI experimentation are the following:

a. **0210 – 0232 hrs:** The HMCS Montreal has been re-tasked from its current mission (FISHPAT) to the CD OP. Alpha 51 and Viper 01 are also re-tasked from their training exercise to the CD OP. In turn, Viper 01 must be vectored by 4 ADR MCE into position and Alpha 51 must begin and maintain tracking of the SOI.

b. **0325 – 0702hrs**: HMCS Montreal controls two UAVs simultaneously (Bingo 61 and Bingo 62) and receives SAR imagery from a third (Viper 01).

c. **0750 – 0812 hrs:** This series of events exercises multiple transfers of UAV payload control between ship board and airborne MCEs.

d. **1110 – 1140 hrs:** Alpha 52 controls two UAVs and monitors their sensor data (Mike 91 and Mike 92) while receiving SAR imagery from a third (Viper 01). This involves Alpha 52 launching Mike 91 as well as assuming control of Mike 92 from a ship board MCE (HMCS Kingston). In addition, Alpha 52 dynamically re-tasks the missions of these UAVs.

e. **1200 – 1432 hrs**: HMCS Montreal briefly controls three UAVs and monitors their sensor data (Bingo 63, Bingo 64, and Mike 92) while receiving SAR imagery from a third (Viper 01). This involves HMCS Montreal launching Bingo 64 to replace Bingo 63 that is on station as well as assuming control of Mike 92 from an airborne MCE (Alpha 52).

f. **1440 – 1525 hrs:** Multiple targets are being tracked while control of UAVs is transferred between Alpha 52, HMCS Kingston and HMCS Montreal. (Similar events take place during the '1200 – 1432 hrs' time period.

g. **1620 – 1700 hrs:** As the tempo of activity increases, the level of UAV sensor operations and frequency of reporting increases respectively.

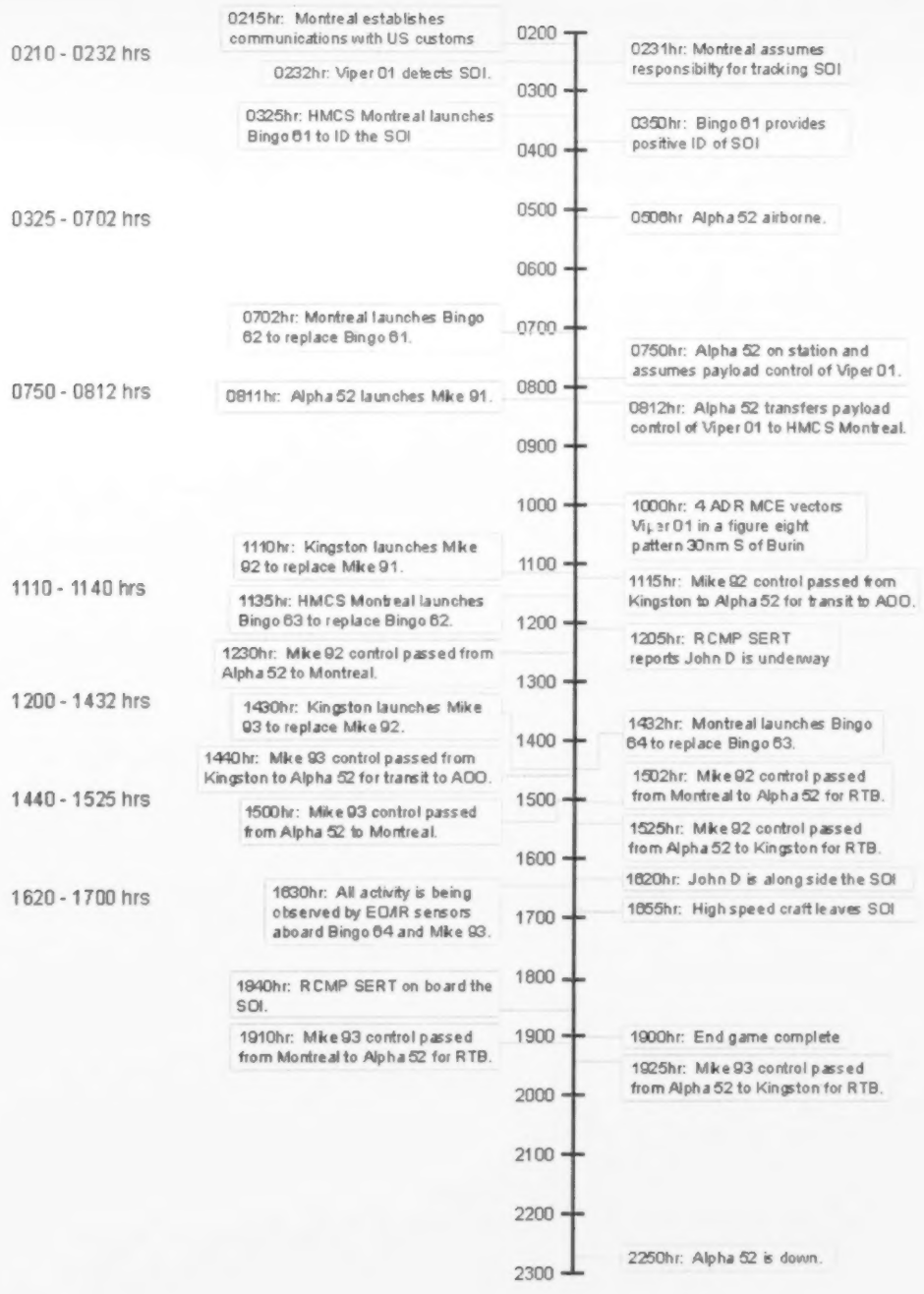
0210 - 0232 hrs
0215hr: Montreal establishes communications with US customs
0232hr: Viper 01 detects SOI.
0325hr: HMCS Montreal launches Bingo 61 to ID the SOI
0325 - 0702 hrs
0702hr: Montreal launches Bingo 62 to replace Bingo 61.
0750 - 0812 hrs
0811hr: Alpha 52 launches Mike 91.
1110 - 1140 hrs
1110hr: Kingston launches Mike 92 to replace Mike 91.
1135hr: HMCS Montreal launches Bingo 63 to replace Bingo 62.
1230hr: Mike 92 control passed from Alpha 52 to Montreal.
1200 - 1432 hrs
1430hr: Kingston launches Mike 93 to replace Mike 92.
1440hr: Mike 93 control passed from Kingston to Alpha 52 for transit to AOO.
1440 - 1525 hrs
1500hr: Mike 93 control passed from Alpha 52 to Montreal.
1620 - 1700 hrs
1630hr: All activity is being observed by EO/IR sensors aboard Bingo 64 and Mike 93.
1840hr: RCMP SERT on board the SOI.
1910hr: Mike 93 control passed from Montreal to Alpha 52 for RTB.
0200
0300
0400
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
0231hr: Montreal assumes responsibilty for tracking SOI
0350hr: Bingo 61 provides positive ID of SOI
0506hr Alpha 52 airborne.
0750hr: Alpha 52 on station and assumes payload control of Viper 01.
0812hr: Alpha 52 transfers payload control of Viper 01 to HMCS Montreal.
1000hr: 4 ADR MCE vectors Viper 01 in a figure eight pattern 30nm S of Burin
1115hr: Mike 92 control passed from Kingston to Alpha 52 for transit to AOO.
1205hr: RCMP SERT reports John D is underway
1432hr: Montreal launches Bingo 64 to replace Bingo 63.
1502hr: Mike 92 control passed from Montreal to Alpha 52 for RTB.
1525hr: Mike 92 control passed from Alpha 52 to Kingston for RTB.
1620hr: John D is along side the SOI
1655hr: High speed craft leaves SOI
1900hr: End game complete
1925hr: Mike 93 control passed from Alpha 52 to Kingston for RTB.
2250hr: Alpha 52 is down.

Figure 22: Timeline of Major Scenario Events

Appendix A USAF UAV C2 Structure

This appendix provides details regarding the USAF Command and Control as well as force structure employed for the MQ-1 and MQ-9 Predators. This data is provided for information purposes as a means to illustrate the implementation of endurance UAVs within the armed forces. This information is predominantly taken from the Concept of Employment for the MQ-1 and MQ-9 Multi-role Endurance Remotely Operated Aircraft [Reference 20] and the Air Combat Command (ACC) CONOPS for Endurance UAVs [Reference 5].

A.1 US Command Structure

Within the US armed forces, operational endurance UAVs are predominately aligned under the Air Force as demonstrated by the two most popular UAV programs, Predator and Global Hawk. MQ-1 and MQ-9 Predator UAVs are currently placed under the ACC's Air Warfare Center (AWC) and assigned to the 57th Wing at Nellis Air Force Base (AFB) (see Figure 23 [Reference 20]). Within the 57th Wing, the Predator was first assigned to the 11th reconnaissance squadron (RS). The 11th RS was activated on 29 July 1995 with the sole purpose of integrating Predator UAVs into air operations. The 11th RS has also been tasked to perform Formal Training Unit (FTU) functions. Subsequently, the second (15th RS) and third (17th RS) Predator squadrons were commissioned in August 1997 and March 2002 respectively. All squadrons are located at Indian Springs Air Force Auxiliary Field, Nevada. In addition, Detachment 4, 53rd Test and Evaluation Group (TEG) performs Force Development Evaluation (FDE). Similarly, Beale AFB in California has been designated as the first Global Hawk main operating base under the 9th Reconnaissance Wing.

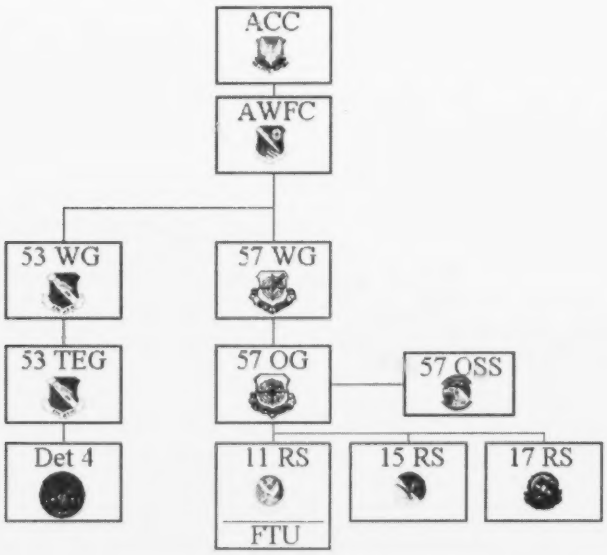

Figure 23: US Command Structure

The proposed MQ-9 force structure parallels the current MQ-1 force structure, with two operational MQ-9 squadrons mirroring the 11th and 15th RS. The composite squadron (17th RS) will operate both airframes, as will Det 4, 53 TEG for consolidated FDE. Organizationally, the FTUs will report through their Wing representative. Det 4, 53 TEG, will be a stand-alone unit with their own administrative and maintenance support.

Operational UAVs that are aligned under the US Army, Marines, or Navy tend to be Medium Range, Short Range, or Miniature variants. For instance, the RQ-7 Shadow 200 resides under the control of the Army and the Dragon Eye is controlled by the US Marine Corps.

A.2 US Force Structure

Within the aforementioned command structure, the Predator force structure will consist of the following:

a. **Two MQ-1 and two MQ-9 Squadrons.** Each squadron will consist of five GCSs, three LREs, and twenty AVs. Three GCSs will be housed within a fixed facility at the MOB and two will be deployable. This force structure allows each unit to conduct a maximum of five simultaneous missions. Each squadron will be manned to simultaneously support one deployed SOC and one MOB SOC.

b. **One MQ-1/9 Composite Squadron**. The composite squadron will consist of two GCSs, three LREs, twelve MQ-1 AVs, and four MQ-9 AVs. Both GCSs will be housed within a MOB fixed facility. All GCSs and LREs will be capable of controlling either AV type. In this capacity, a unit can conduct two simultaneous missions in support of taskings.

c. **One FTU for each airframe.** Each FTU will consist of three GCSs, one LRE, and twelve AV. Two GCSs will be at a MOB fixed facility while the third will be deployable. FTU training will be contract; ACC manning is only required for maintenance and administrative overhead.

d. **Operational Test Assets.** Detachment 4, 53rd TEG will perform FDE with two deployable GCSs, one LRE, four MQ-1 AVs and four MQ-9 AVs. The GCSs and LREs will be capable of controlling either AV type.

e. **One Backup GCS and LRE.** One GCS and one LRE are required to permit upgrades and periodic depot-level maintenance. No ACC manning is required for either element.

f. **Attrition Aircraft.** Once there is sufficient historical data to plan for training and operational losses, sufficient numbers of AV will be programmed.

The ACC force structure requirements for the Predator are summarized below in Table 5 [Reference 20].

Table 5: ACC Force Structure Requirements

Unit	GCS (fixed)	GCS (mobile)	LRE	MQ-1 AVs	MQ-9 AVs
11 RS	3	2	3	20	0
15 RS	3	2	3	20	0
17 RS	2	0	3	12	4
MQ-1 FTU	2	1	1	12	0
YY RS	3	2	3	0	20
ZZ RS	3	2	3	0	20
MQ-9 FTU	2	1	1	0	12
FDE	0	2	1	4	4
BAI	0	1	1	0	0
TOTAL	**18**	**12**	**18**	**68**	**60**

A.3 US Command and Control

Combat Command (COCOM) of DOD operational endurance UAVs is controlled by United States Atlantic Command (USACOM). OPCON of these assets is the responsibility of the ACC, USACOM's Air Force component. Once a deployed endurance UAV has reached its area of responsibility, OPCON transfers to the theater Commander in Chief (CINC).

A.3.1 Domestic and Peace-Support Operations

During peacetime, endurance UAVs will be based in the United States under the COCOM of the USACOM with ACC providing OPCON. Example operations include:

a. **Training and Exercise.** CINCs can request endurance UAVs through the Joint Chief of Staff (JCS)/Reconnaissance Operations Division (ROD). The ROD allocates forces for training and exercises. Based on the ROD's allocation, USACOM tasks ACC to support the requesting theater CINC's exercise and training needs.

b. **Peacetime Deployment.** UAVs and ground stations supporting exercises will fall under the supported CINC's exercise command structure for exercise tasking.

c. **Sensitive Reconnaissance Operations (SRO).** When deployed to support real-world reconnaissance operations, short of crisis or war, endurance UAVs will "chop" to the theater CINC or designated OPCON representative. During these operations, endurance UAV collection efforts are primarily directed towards satisfying theater CINC and National Command Authority (NCA) requirements. The JCS/ROD combines the inputs from the warfighting Commands with other government agency requirements (see Figure 24 [Reference 5]). These requirements are then sent to the Defense Intelligence Agency (DIA) and the National Security Agency (NSA) for

validation. Validated requirements are subsequently forwarded to the National Security Council (NSC) for approval (see Figure 25 [Reference 5]). Upon approval, the ROD then notifies the theater CINCs of the approved SRO schedule. USACOM (through ACC) provides forces to theater CINCs, who in turn, execute each mission based on local conditions. As with all SRO, the tasking approval authority remains embedded within the JCS Reconnaissance Schedule Approval/Execution Process ("Book Process").

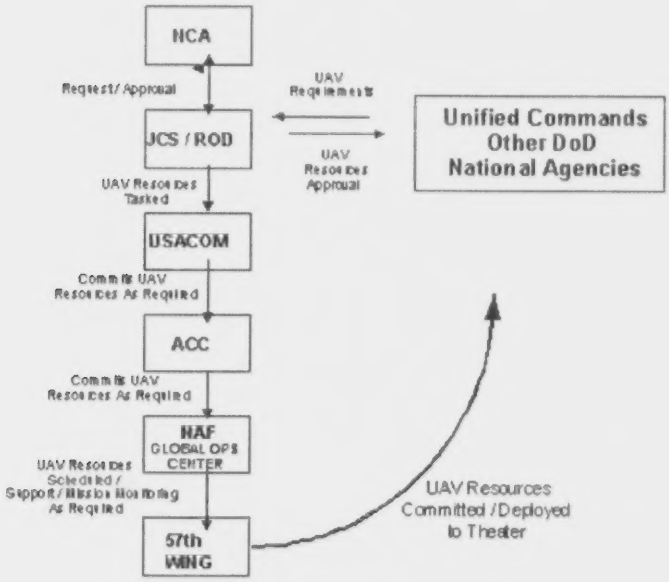

Figure 24: Predator Endurance UAV Peacetime Tasking Flow to Theater

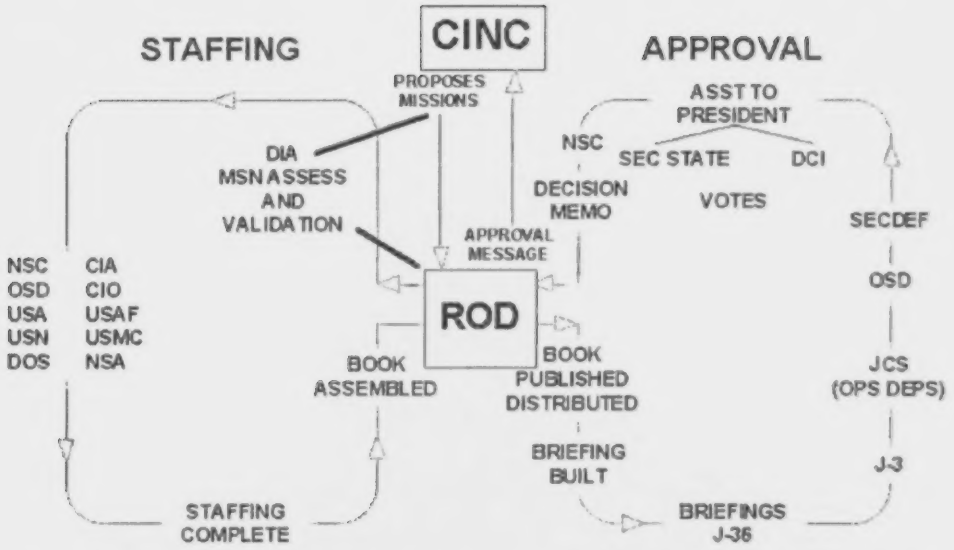

Figure 25: JCS Reconnaissance Schedule Approval / Execution Process "Book Process"

A.3.2 War-fighting Operations

During contingency operations or support of wartime operations, the UAV becomes a theater asset with COCOM dedicated to the appropriate Unified CINC or JFC. Execution of the endurance UAV role in the JFC's campaign plan (i.e. OPCON) will be the responsibility of the Joint Force Air Component Commander (JFACC) as delegated by the JFC. The JFACC must establish a process for integrating the UAVs in the overall Airspace Control Plan (ACP) developed by the Area Air Defense Commander (AADC) and the Airspace Control Authority (ACA). The ACP will have detailed procedures for UAV operations to resolve manned and unmanned operations in joint use airspace; these procedures should cover both pre-planned UAV missions as well as allow for contingency flight path/mission deviations. Specific procedures will be contained in the ATO. To ensure flight safety and effective asset allocation, Tactical Control (TACON) is relegated to the air component operational chain of command.

Collection management will reside in intelligence (J2 and A2) channels, but will be a subset of airborne asset command and control by the A3 in the AOC. Collection requirements for UAV operations will be reviewed, validated, and prioritized by the J-2. The J-3, in coordination with the J-2, will forward these requirements to the commander exercising TACON over these theater reconnaissance and surveillance assets, as depicted below in Figure 26 [Reference 20]. The component commander will then task the asset to satisfy the JFC requirement.

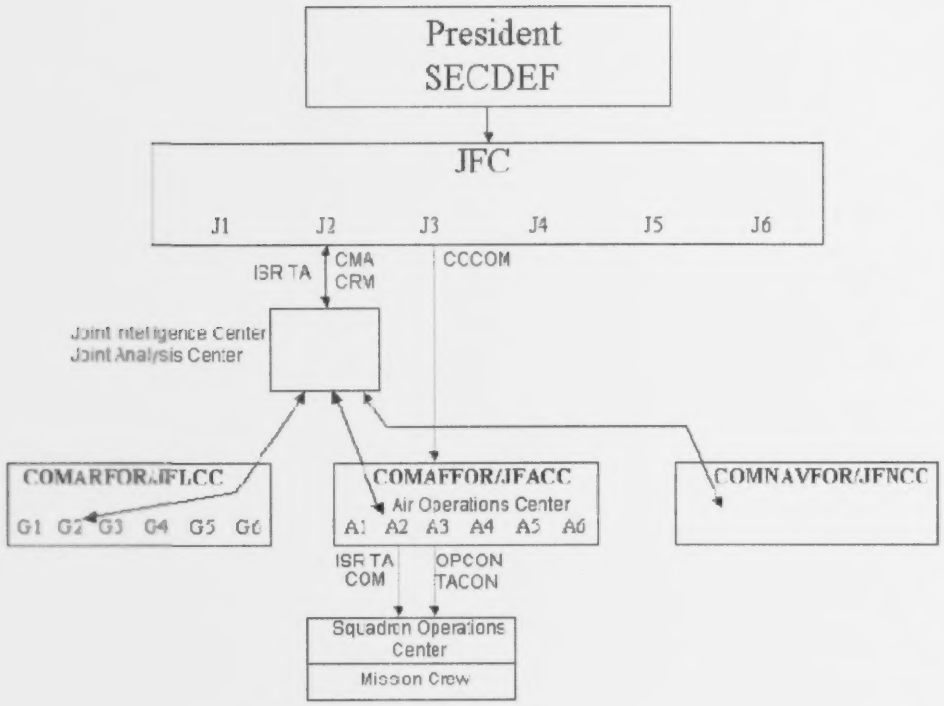

Figure 26: Endurance UAV Wartime Tasking Procedures

A.3.3 Single Integrated Operational Plan (SIOP)

As directed by National Command Authority, USACOM will provide endurance UAVs as required to support taskings from US Strategic Command (USSTRATCOM). Once allocated for use by USSTRATCOM, these assets become dedicated force enhancement assets managed by Commander Task Force 224 (CTF 224) Battle Management. This SIOP tasking process is depicted in Figure 27 [Reference 5].

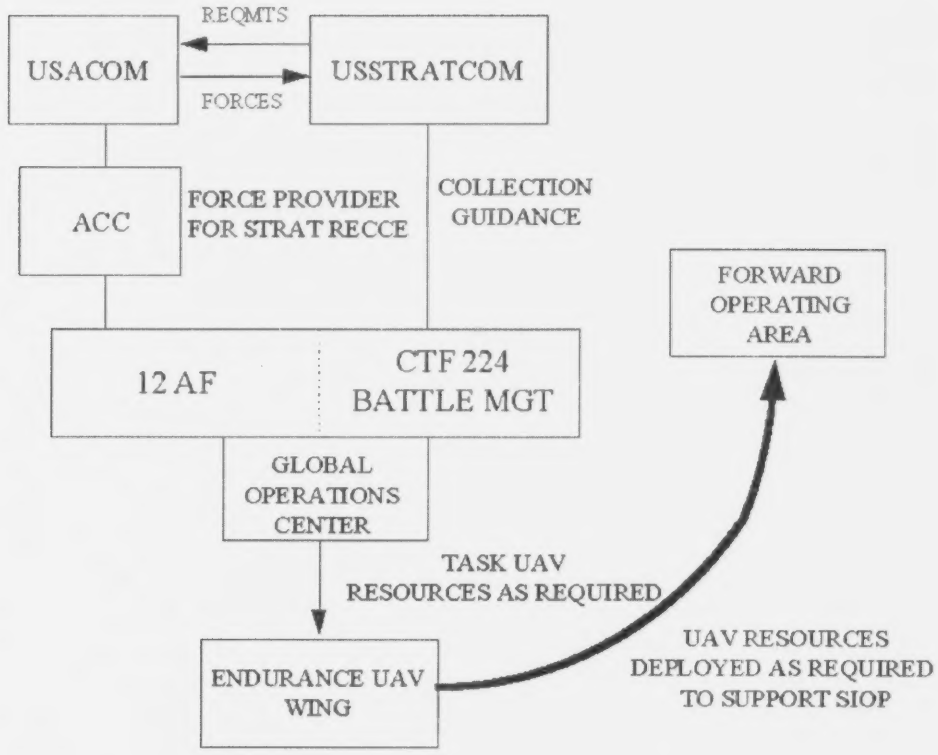

Figure 27: Endurance UAV SIOP Tasking Procedures

A.4 11th RS Crew Composition

The 11th RS within the USAF is subdivided into operations and maintenance for the Predator UAV (as depicted in Figure 28 [Reference 5]). The basic crew for the Predator is one pilot and two sensor operators. All squadron personnel will have a worldwide commitment to deploy in support of tactical operations or other taskings as appropriately approved.

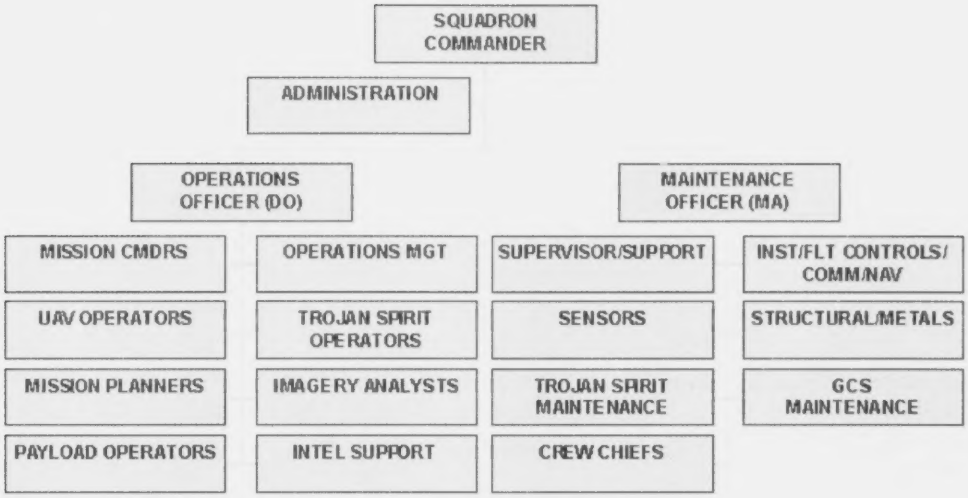

Figure 28: 11th RS Crew Composition

Appendix B Predator UAV System Components

This appendix provides details regarding the employment and capabilities of the Predator family of UAVs. The majority of information has been extracted from the USAF Concept of Employment for the Predator UAV [Reference 20].

The Predator UAV is a system, not just an aircraft as depicted in Figure 29. A fully operational system consists of four Predator air vehicles with sensors/payload, flight control (either a ground control station (GCS) with Predator Primary Satellite Link (PPSL) or Continental US (CONUS) fixed facility with LRE), and required personnel for continuous 24 hour operations.

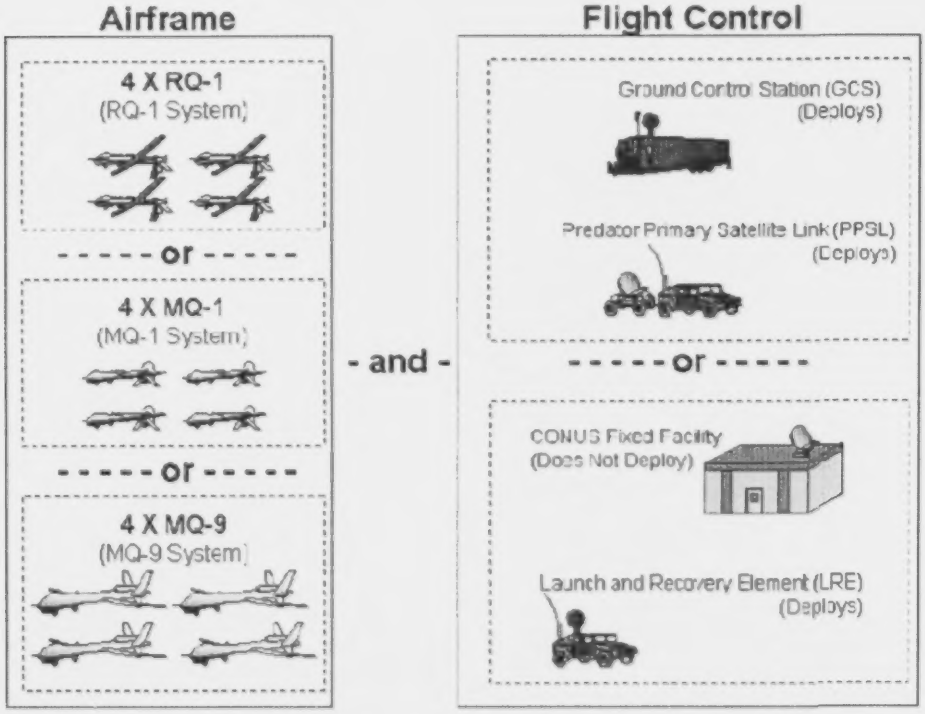

Figure 29: Predator System Components

Details regarding the Predator air frame are provided in Section B.1. Flight control details outlining the GCS and PPSL configuration and the CONUS fixed facility and LRE flight control configuration are presented in Section B.3. The Predator LOS and BLOS communication capabilities are described in Section B.4. Finally, Section B.5 outlines the personnel requirements to support either a deployed GCS or a LRE.

B.1 Air Vehicle Characteristics

The RQ-1/MQ-1 Predator UAV is roughly half the size of an Air Force F-16 fighter with long, thin wings and a tail like an inverted V. The MQ-9 Predator B is a larger low-wing monoplane with narrow fuselage and high aspect-ratio wing, large Y-shaped tail, with ventral vertical fin, and a rear-mounted turboprop or turbofan engine. Other features include an enlarged fuselage nose to accommodate various payloads, retractable tricycle landing gear, and dual-redundant flight controls. The characteristics for each AV are summarized in Table 6 and depicted in Figure 31 [Reference 8] and Figure 30 [Reference 26].

Note: Certain characteristics such as endurance and payload vary across references. As a result, Reference 20 was taken as the overriding document for any inconsistencies.

Table 6: Predator AV characteristics

Characteristic	RQ-1/MQ-1 Predator Dimensions	MQ-9 Predator 001 Dimensions
Dimensions		
Wingspan	48.7 ft (14.84 m)	66 ft (20.2 m)*
Length	27 ft (8.23 m)	36.2 ft (11 m)
Height	7.3 ft (2.2 m)	11.8 ft (3.6 m)
Wing Aspect Ratio	17.5	17.5
Weight		
Empty	1,200 lbs (544 kg)	
Fuel	650 lbs (295 kg)	3,000 lbs (1364 kg)
Payload	450 lbs (204 kg)	750 lbs (340 kg) – internal 1500 lbs (682 kg) - external
Max Takeoff	2,300 lbs (1,043 kg)	6,500 lbs (2955 kg)
Speed		
Cruise	111-120 km/hr (60- 65 kts)	
Loiter	120-130 km/hr (65- 70 kts)	
Maximum	204-215 km/hr (110-115 kts)	407 km/hr (220 kts)
Altitude		
Operating	10 000 – 15 000 ft	
Maximum	25,000 ft. (7620 m)	50,000 ft. (15 240 m)
Climb Rate (max)	550 fpm (168 m/min)	
Mission Duration Operating Radius	16 hrs on station at 400 nm	16 hrs on station at 650 nm
Maximum Endurance	26 hrs at 20,000ft	20 hrs at 30,000 ft

* The Predator Altair wingspan is 86 ft

Even though the Predator B can fly twice as high as and significantly faster than its predecessor, it does not exhibit longer endurance characteristics. One reason for the reduced endurance is the increased drag associated with carrying external payloads such as Hellfire missiles. This is one reason why the Predator B is considered a "hunter-killer" whereby it goes out, locates the enemy, persists in the area until it identifies the target, and then attacks.

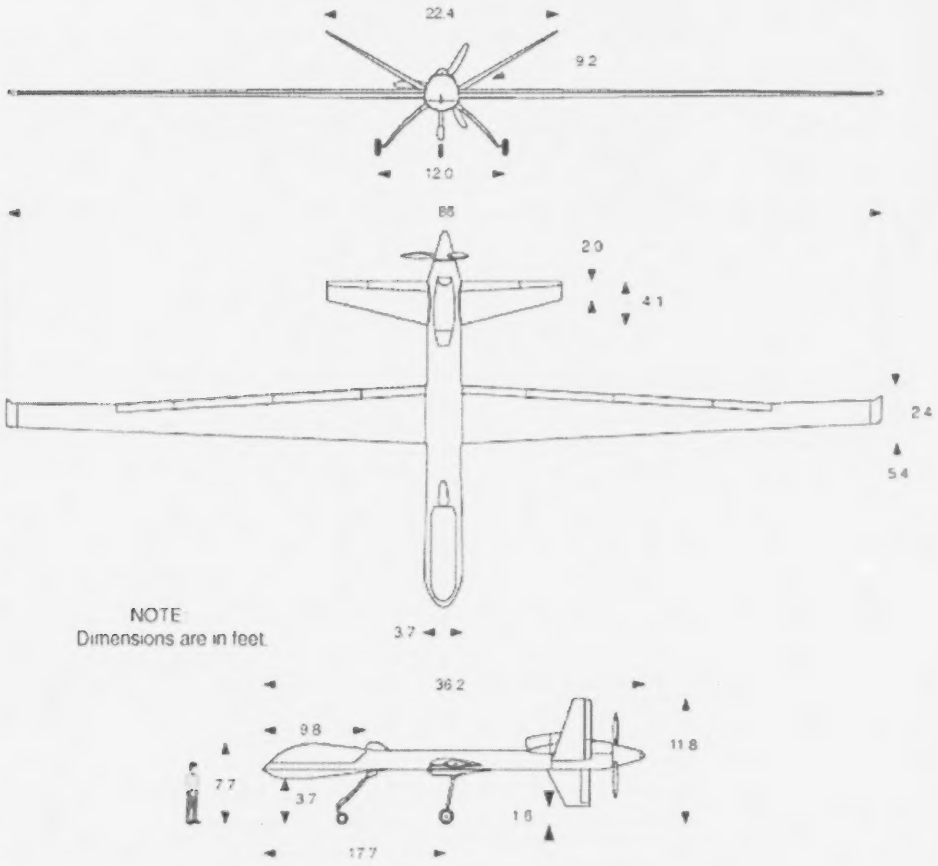

Figure 30: Predator B Dimensions (Altair version)

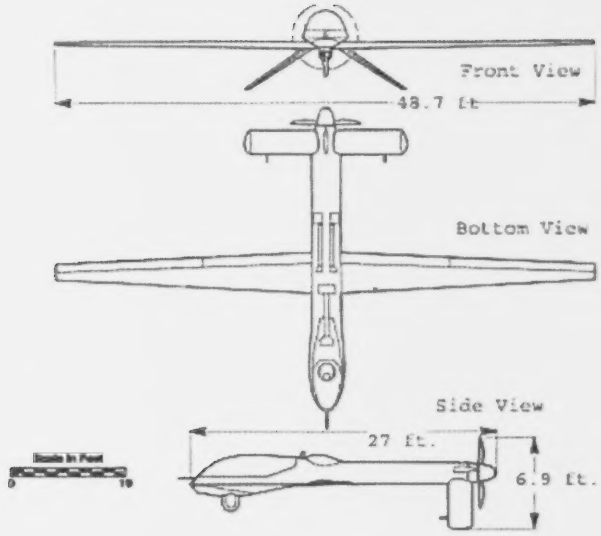

Figure 31: RQ-1/MQ-1 Predator Dimensions

B.2 Payload

This section provides an overview of the payloads previously employed by the Predator UAV. The larger Predator B can carry a heavier payload than its predecessor which provides flexibility with respect to the type of external payload that it can be employ. It must be noted that the precise payloads for the Predator-B have yet to be fully defined as the USAF is currently investigating potential technologies for satisfying the anticipated mission needs for this UAV.

B.2.1 Electro-Optical/Infrared

The Predator UAV has or will have the following EO/IR payloads:

a. RQ-1 employs the Wescam 14 which contains an EO with 16-160mm zoom; an EO with 955mm Telephoto; and Medium Wave Infrared (MWIR).

b. MQ-1 employs the Raytheon Multi-Spectral Targeting System as its primary payload sensor, containing EO and Long Wave Infrared (LWIR) sensors, a laser range finder, laser target marker and laser target designator.

c. MQ-9 is scheduled to possess capabilities such as EO, LWIR, Near IR, Ultraviolet (UV), Infrared Search and Track, and Video (EO/IR/UV) Automatic Target Recognition (ATR).

In addition, Reference 20 indicates the Predator B will support the following related capabilities:

a. **Fused Hyper-spectral Imaging.** This capability allows simultaneous sensing across multiple bands of the electromagnetic spectrum. The resulting data can be fused into

a single hyper-spectral video stream for automatic processing of irregularities which can, in turn, be designated as targets. Target bands include:

- Visual spectrum. This spectrum is required to provide positive identification and description of detected targets.
- Near Infrared. Laser target designators, laser target markers and combat search and rescue signaling devices op ate in this band.
- Long Wave Infrared. The LWIR band provides a more thermally sensitive detection capability for imaging and anomaly detection than near IR.
- Ultraviolet. UV helps to overcome camouflage, concealment, and deception techniques effective within the IR and the visual spectrums.

b. **Automatic Search Pattern/Infrared Search and Track.** With this capability, the sensor is able to automatically search a given raster with a pattern representative of the target type and location and subsequently cue "hot spots". The operator can then designate displayed IR returns as targets. If the operator breaks the lock on a specific target; the sensor would then continue with the raster search, locking on the next available IR source.

c. **Automatic Target Recognition.** Based on fused data from all onboard sensors, video processors will perform real-time ATR. In addition, system generated exploitation products will include automatic symbology and annotation of identified targets.

Examples of single-frame Predator imagery from missions over Bosnia are shown below in Figure 32 [Reference 9].

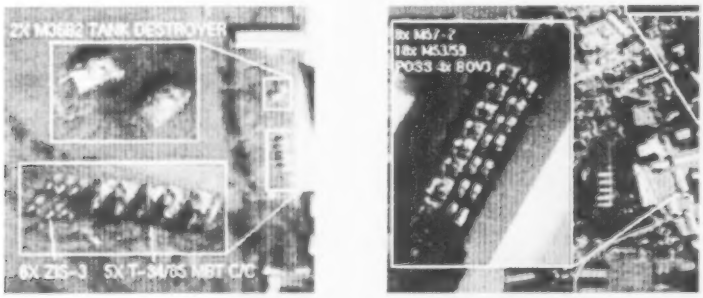

Figure 32: Predator EO and IR snapshots

B.2.2 Synthetic Aperture Radar

In addition to the EO/IR payload, Predator UAVs have traditionally carried a complimentary synthetic aperture radar. On board the RQ-1/MQ-1 Predator, the Tactical Endurance Synthetic Aperture Radar (TESAR) from Northrop Grumman is a strip mapping SAR providing continuous 0.3 meter (1 foot) imagery (refer to Figure 33 [Reference 10]). The focused imagery is formed on-board the AV, compressed and sent to a ground control station via the Ku band data-link (compressed and continuous SAR imagery is not available in the LOS/UHF modes of operation). The imagery is reformed and displayed in a scrolling manner on the SAR

workstation displays. As the imagery is scrolling by, the operator has the ability to select 1k by 1k image patches (approximately 800m by 800m box at 15,000 AGL) for exploitation within the ground control station. Figure 34 [Reference 9] illustrates a snapshot of a single-frame SAR image from the Predator.

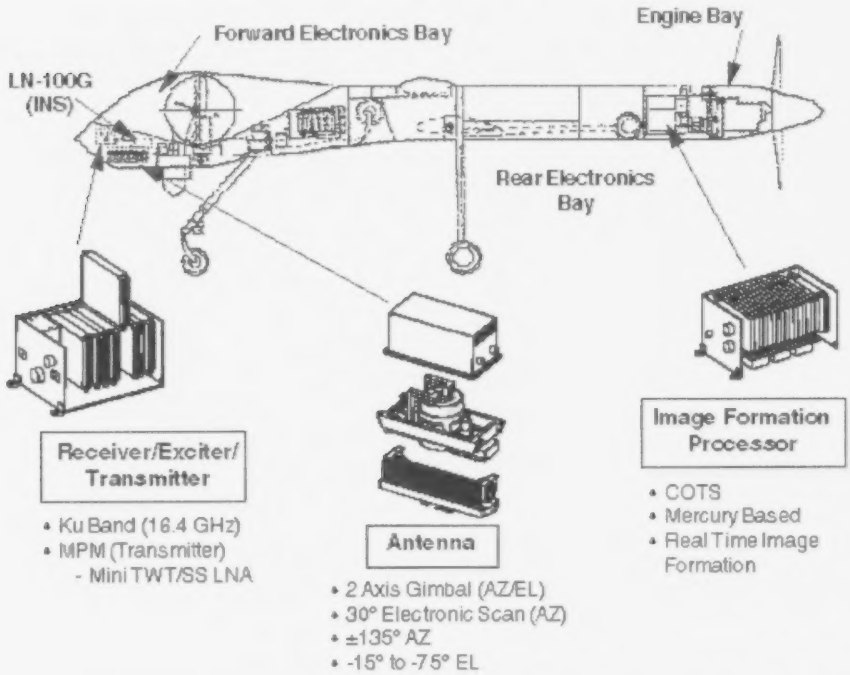

Figure 33: Predator TESAR Payload from Northrop Grumman

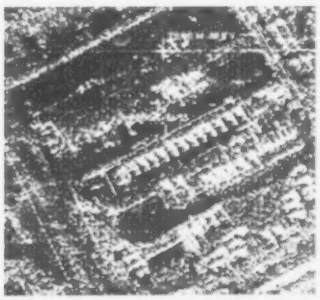

Figure 34: Predator SAR snapshot

Since the initial deployment of the RQ-1 Predator, the TESAR payload has been upgraded by Northrop Grumman to include a moving target indication mode in addition to the SAR mode. In MTI mode, the radar provides target reports overlaid on a digital map. This new

payload has since been incorporated and flight-tested with UAVs such the US Army Hunter and the UK Watchkeeper.

As a substitute to the TESAR, the US Sandia National Laboratory in collaboration with General Atomics developed the improved "Lynx" SAR/Ground MTI radar system that is compatible with the Predator (http://www.lynxsar.com/home.html). Currently, the Lynx SAR weighs approximately 52 kg (115 lbs) and operates in Ku-band. The sensor can produce higher resolution images (up to 10 cm) in SAR mode and tracks of moving targets on the ground in Ground MTI mode.

Although not fully defined, the MQ-9 will employ a payload that provides SAR, SAR-MTI, and SAR-ATR capabilities.

B.2.3 Weapons

Weapons will become a common payload employed on the Predator B. For instance, all MQ-1 Predators coming off the assembly line will be capable of carrying two Hellfire missiles (AGM-114K/M), while older Predators are planned to be retrofitted to carry the missile. The weaponization of the Predator was a result of lessons learned during the 1999 NATO air campaign against Yugoslavia. By the time an attack aircraft arrived on a military target located by a Predator, the target was gone. Arming Predators allows identified targets to be attacked immediately. The USAF plans to arm the MQ-9 Predator B as depicted in Figure 35 [Reference 20]).

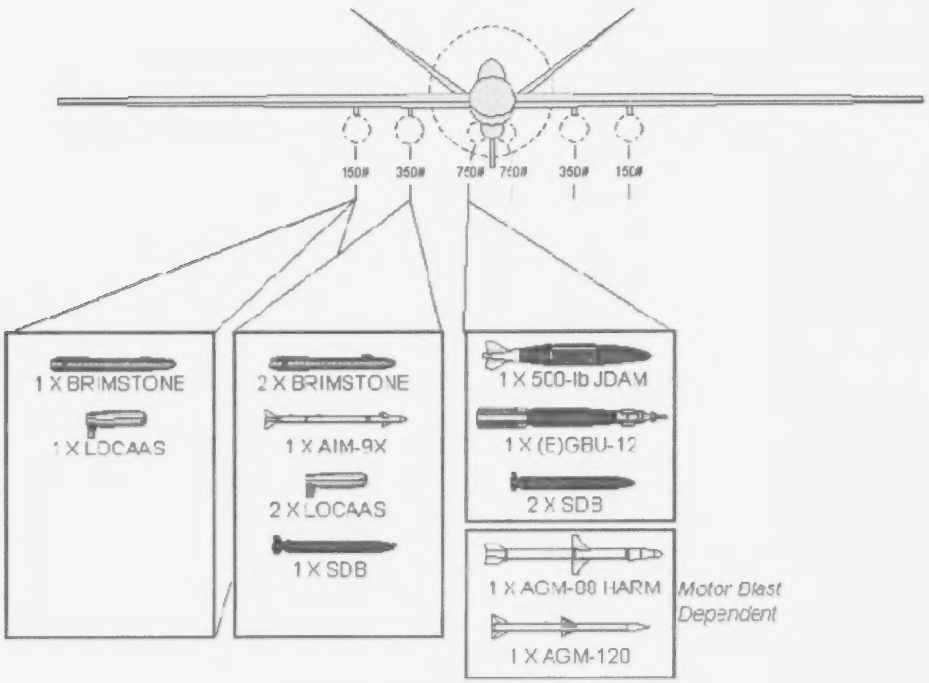

Figure 35: MQ-9 Weapons Roadmap

The current Hellfire is not a viable option for the Predator B since this UAV flies higher than its predecessor and these missiles are neither operationally qualified at cold temperatures resident at these altitudes nor do they have the range to hit targets from these altitudes. The weapons of choice for the Predator B are still being investigated with potential candidates including:

a. GPS-guided 250-lb.-class Small-Diameter Bomb (SDB);

b. Air-to-surface missiles such as laser-guided AGM-114 Hellfire II, Low Cost Autonomous Attack System (LOCAAS) mini-cruise missile, and AGM-65 Maverick

c. GBU-12 500 lb laser-guided bomb; and

d. Air-to-air weapons like AIM-9 Sidewinder, FIM-92 Stinger, and AIM-120 Advanced Medium-Range Air-to-Air Missile.

In addition, the Predator may employ a laser range finder, laser target marker and laser target designator.

B.3 Flight Control

As depicted in Figure 29, there are two options for controlling the Predator UAV while in flight, which are:

a. Ground Control Station and PPSL (see Figure 36); or

b. Launch and Recovery Element and CONUS fixed facility (see Figure 38).

B.3.1 Ground Control Station and Primary Predator Satellite Link

With this configuration, the GCS is responsible for operating the AV, payload sensors, and laser designator, as well as employing weapons. In addition, the GCS disseminates information obtained from the AV to the Squadron Operations Center (SOC). The GCS should be capable of basic data processing and exploitation as well as allowing a mission crew to independently perform identification, surveillance, and destruction of a target if required.

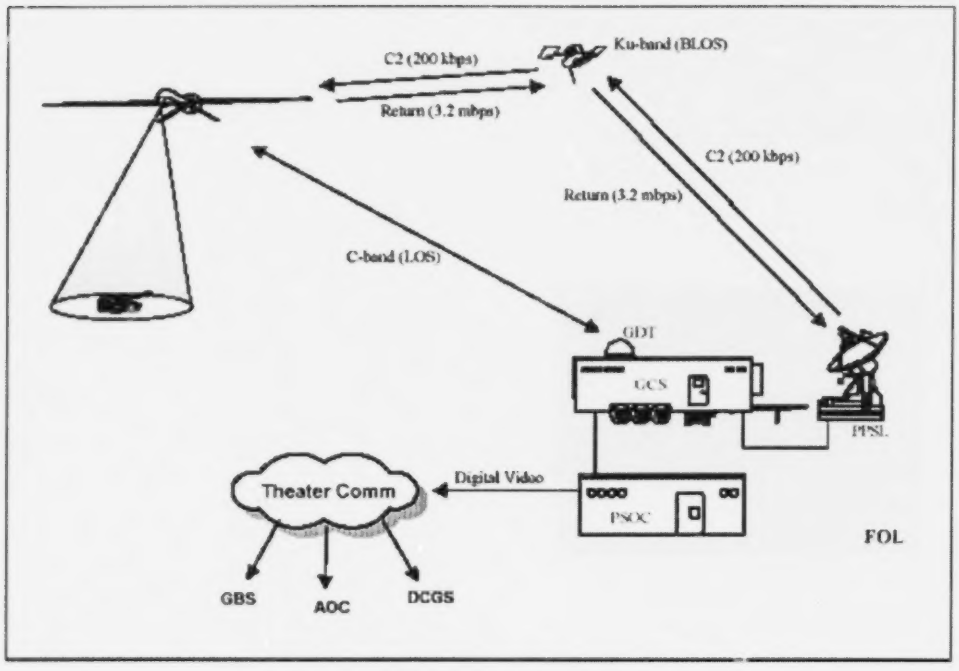

Figure 36: Predator GCS and PPSL

.The Predator GCS which is housed in a 30ft x 8ft x 8ft commercial van (Figure 37 [Reference 11]) consists of the following workstations:

a. **Pilot and payload operator (PPO).** These workstations, which are interchangeable, provide the primary means for controlling the air vehicle and sensor payload.

b. **Data Exploitation, Mission Planning and Communications (DEMPC).** The three consoles facilitate imagery data exploitation, mission planning, mission and payload monitoring, and system management.

c. **SAR.** These two workstations control and monitor the SAR as well as support limited exploitation of the SAR data. The TESAR GCS elements provide the primary image display and diagnostics for the SAR payload.

d. **Communication.** Also included in the GCS is the Ground Data Terminal (GDT) which employs the C-band link to launch and recover the AV, control the AV and downlink video within LOS. In addition to the LOS capabilities, a PPSL terminal can establish a Ku-band commercial satellite communications link for missions that are BLOS of the GDT. Details of the communication capabilities are reserved for Section B.4.

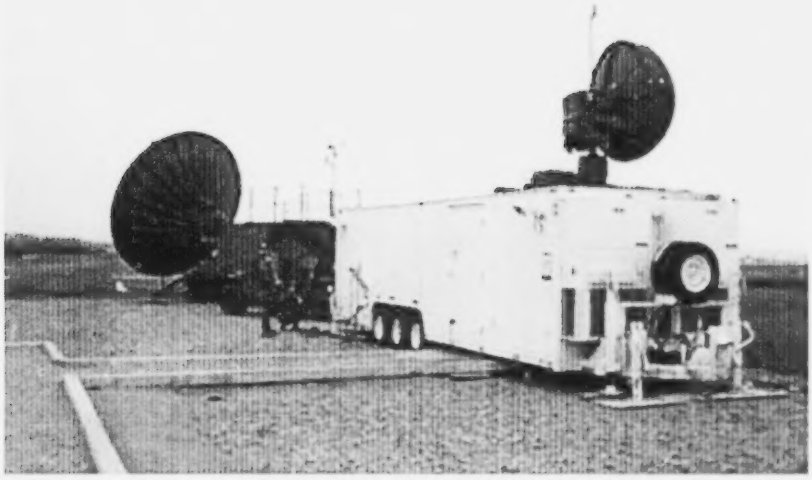

Figure 37: Predator GCS and Trojan Spirit II

The SOC digitizes, compresses, and encrypts the video it receives from the GCS prior to disseminating the video product.

B.3.2 CONUS Main Operating Base and LRE

The CONUS Main Operating Base (MOB) serves as a central node for global mission execution of Predator UAVs. The GCS located at the MOB controls the aircraft and downlinks the video via a satellite terminal at a Regional Satellite Node (RSN). The RSN is connected to the GCS using a communications architecture such as the Defense Information Systems Agency (DISA) Information System Network (DISN). In conjunction with the CONUS MOB, a GDT on a forward-deployed LRE can be used for landings and takeoffs of air vehicles through LOS control. Control of an airborne AV would be handed over to the CONUS MOB for conduct of the mission and subsequently handed back to the LRE when the AV has returned for landing. Similar, to the GCS-PPSL setup, the SOC at the MOB prepares the video received from the GCS for subsequent distribution to the appropriate individuals.

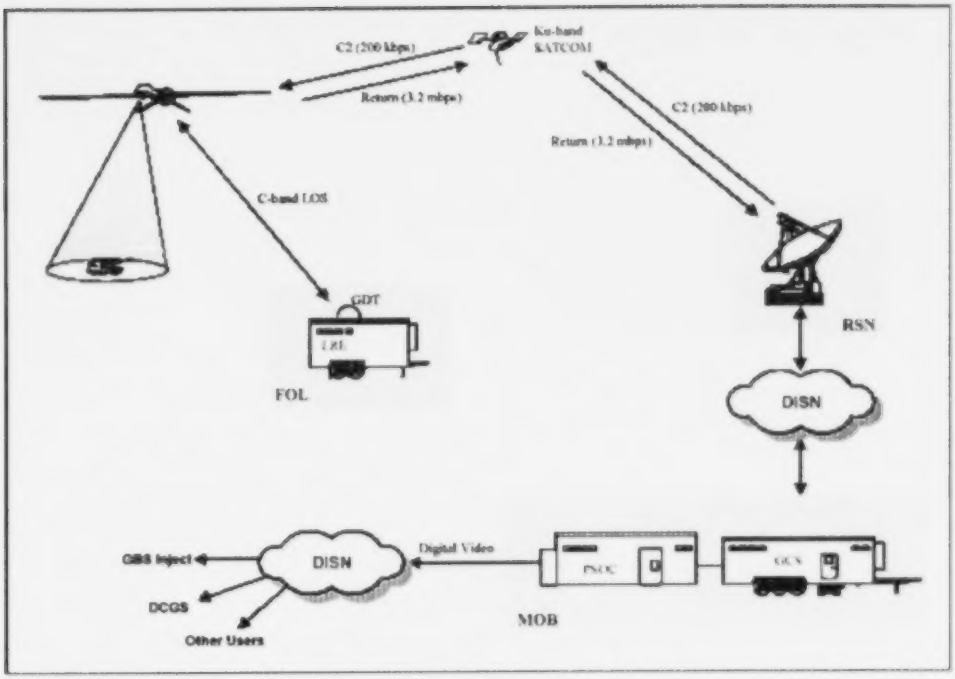

Figure 38: Predator CONUS and LRE

B.4 Communications

This section elaborates upon the communication set-up for the Predator UAV system including the two-way communication between the AV and GCS as well as the communication between the GCS and the rest of the operational community.

B.4.1 Internal Communications

A GDT on the GCS or LRE is used to launch and recover the AV using C-band LOS communications. The C-band link can also be used to control the AV and downlink data within LOS of the GDT. However, this link interferes with the ground infrastructure communications networks within some countries. The proposed thrust is to integrate a Tactical Common Data-Link (TCDL) capability for the Predator LOS as means to address this issue.

For a BLOS communications between the GCS and AV, the Predator UAV system employs a Ku-band SATCOM data-link to relay colour video in real time to commanders. Either a PPSL terminal or Regional Satellite Node is used to establish this link. In either configuration, the BLOS link consists of a 200 kbps (9 MHz) C2 uplink from the GCS to the AV, and a 3.2 mbps (6 MHz) sensor and data return link from the AV to the GCS. For BLOS communications, a UHF SATCOM capability is also available; however, this link is seldom used due to its low data transfer rate (4.8 kbps). In fact, the transfer rate is not sufficient for transmitting SAR imagery.

B.4.2 External Communications

Within the Predator UAV system, external communications are via HF/UHF/VHF (voice/data), cellular/landline telephones, and hardwire connectivity with the TROJAN SPIRIT II (TS II) satellite communication terminal. Other SATCOM systems may be employed to link the GCS to an intelligence architecture.

The TS II is an Army satellite communications terminal and system providing access to system tasking authorities, dissemination networks, and exploitation systems. Equipment consists of two high-mobility multi-purpose wheeled vehicles (HMMWV) with shelters, two trailer-mounted SATCOM antennas, and two diesel-powered generators. The larger 6 m satellite dish provides the aforementioned BLOS communications between the GCS and AV. The smaller 2.4 m dish within the TS II provides the capability to pass selected imagery from the GCS into Joint Deployable Intelligence Support System (JDISS) via Joint Worldwide Intelligence Communications System (JWICS) connectivity in the TROJAN SPIRIT network. The JDISS is a data dissemination and processing system that is located in the TS II.

B.5 Personnel Requirements

Reference 20 provides details regarding the personnel requirements for deployments through deployed GCS or split operations.

Deployed GCS operations consists of a GCS, four AV, Operations Center, PPSL, and logistics support equipment sufficient for 30 days of continuous operations at a forward MOB. Each AV is configured with the MTS sensor, SAR, and weapons. To support this configuration, a total of 82 individuals are required with 31 in the Operations Section, 45 in the Maintenance Section, 3 in the Admin Section, and 3 Liaison Officers.

For split operations, the forward presence consists of the LRE equipment, four AV, and logistics support equipment sufficient for 30 days of continuous operations at the FOL. The associated LRE manning consists of 3 pilots in the Operations Section, 40 individuals in the Maintenance Section, and 1 Medical Technician in the Support Section. The home station comprises 33 individuals in the Operations Section and 8 in the Maintenance Section. Split operations require a total of 85 individuals.

For both types of deployment, security, lodgment, and messing are provided as Base Operating Support at the deployed location.

Appendix C Original Scenario

C.1 General

This appendix includes the original scenario that was submitted to DRDC to satisfy their experimental requirements. The mission scenario will provide a framework to illustrate the mission elements described in the mission analysis and identify the unique mission-critical operational activities performed by the UAV MCE team on an airborne platform. The primary objective in developing a mission scenario is to provide a baseline for future analysis activities and experimentation using UAVs/UCAVs to evaluate the impact of various Intelligent Adaptive Interfaces. Although the number of UAVs that the MCE can be expected to manage simultaneously is unknown at present the scenario is designed to expose the airborne UAV MCE team to the maximum workload that could realistically be expected.

C.2 Scenario Overview

The mission chosen for the scenario is a counter drug operation conducted in conjunction with a routine fisheries surveillance patrol as this represents a realistic domestic operations tasking received by the Canadian Forces in peacetime. In fact, the Canadian Forces conducts several counter-drug operations, in support of RCMP operations, every year on both East and West coasts.

The mission for the UAV in the conduct of a CD OP or FISHPAT is an Intelligence gathering, Surveillance and Reconnaissance mission. ISR are unique tasks, yet there is considerable overlap in how these three tasks are accomplished by UAVs and in the information that is acquired by their execution. As a result, the three tasks will be integrated into a single task for the purposes of this scenario.

The operational level commanders for domestic operations, including CD OPs and support to other government departments are: Commander MARLANT, Commander MARPAC, Land Force Area (LFA) Commanders, Commander 1 CAD, and Commander Canadian Forces Northern Area HQ (CFNAHQ). Operational level commanders are responsible directly to the CDS.

CF counter drug operations are governed by a Memorandum Of Understanding (MOU) between the Minister of National Defence (MND) and Solicitor General that specifies the support the CF may supply. Support under the MOU is limited to surveillance, intelligence sharing and interdiction. Any other support must be the subject of a separate request from the Solicitor General to the MND. CF counter drug operations are coordinated at the National Defence Headquarters (NDHQ) level by the Chief of Staff Joint Operations (COS J3), who maintains a liaison cell (CFLO RCMP) with the RCMP.

C.3 Assumptions

The assumptions regarding factors such as the UAV system employed, manning, and participating units are detailed in Table 7.

Table 7: Scenario Assumptions

Category	Assumptions
UAV System	• All UAVs will be Predator type with a payload of EO/IR and SAR sensors. • The baseline level of autonomy for the UAV system will be consistent with the Predator. Future evolutions of the system as defined through experimentation will subsequently increase the UAV's autonomy level. • The airborne MCE will be onboard a CP-140 Aurora. • The ship based MCE will be in the operations room onboard a Canadian Patrol Frigate (CPF). • 4 ADR LRE has a co-located MCE. • Communications bandwidth will be provided as required by the UAV and controlling agency. • The UAV remains in the positive control, including both flight and sensor operation, of the controlling agency at all times.
Manning	• All MCEs have adequate manning to permit 24hrs operations for at least 3 days. • Based on current practice, each MCE will be manned with a qualified pilot who will be dedicated to the flight control of UAVs. • CP-140 Aurora manning will be from the current mission crew augmented by a qualified pilot as the AV operator. The Tactical Navigator (TACNAV) will serve as mission commander, and a Non-Acoustic Sensor Operator (NASO) as payload operator. • Ship based manning will be from the operations room team augmented by a qualified pilot as the AV operator. The Operations Room Officer (ORO) will serve as mission commander, and the Sensor Weapons Controller (SWC) as payload operator. • Land based MCE manning consists of a combat arms officer as mission commander, a combat arms Non Commissioned Member (NCM) as payload operator and a qualified pilot as AV operator.
Participating Units	• CP-140 Aurora (x2) • Canadian Patrol Frigate (x2) • 4 Air Defence Regiment (ADR) • RCMP SERT (x2)

Table 7: Scenario Assumptions

Category	Assumptions
General	• Weather is Visual Flight Rules (VFR). • The Sea King Helicopter on the HMCS Montreal is unserviceable. • Air traffic control will provide altitude reservations for UAVs transiting to and from the AOO and have given authority to CF MCEs to provide control in the AOO. • The AOO is a block of airspace 200nm by 200nm south of Halifax.

C.4 Situation

C.4.1 General

The time is 0100 hours 21 Mar 04. The situation at the beginning of the scenario is that 3 days ago the RCMP through the CFLO RCMP generated a request for CF support in a CD OP to be conducted in the next 12 to 24 hours. In response to this request NDHQ has initiated a CD OP code name "Helping Hand 2004-01". The goal of a CD OP is to detect, track, and intercept ships and aircraft in order to prevent the delivery of narcotics into Canada.

NDHQ appointed Commander MARLANT to act as Task Force Commander Atlantic (TFCLANT). Maritime Air Commander Atlantic (MAC-A) is appointed as the Air Component Commander Atlantic, Commander Atlantic Fleet (LANTFLT) is designated as the Maritime Component Commander Atlantic and Commander Land Forces Atlantic Area is designated the Land Force Component Commander.

The mission will be coordinated from the MARLANT Headquarters at Canadian Forces Base (CFB) Halifax.

The RCMP has deployed two Special Emergency Response Teams (SERTs). Team 1 will take up ground positions in the vicinity of Yarmouth, Nova Scotia before 0800 hours. Team 2 has been taken aboard HMCS Winnipeg which has been tasked to support the mission.

The Ship Of Interest (SOI) is presently being tracked by US Customs aircraft working with a US Coast Guard vessel.

Concurrent with this activity HMCS Montreal is conducting a FISHPAT approximately 180nm southeast of Halifax. The HMCS Montreal has one UAV that was launched from CFB Greenwood 12 hours ago, under its control. The Sea King Helicopter on board the HMCS Montreal is unserviceable.

All mission planning has been completed and units are preparing to deploy.

C.5 Factors Effecting the Mission

C.5.1 Participating Forces

The CF operations are conducted in concert with a number of government departments and organizations including the Canadian Security Intelligence Service (CSIS), RCMP, the

Communications Security Establishment (CSE) and Canadian Coast Guard. In addition, the CF and RCMP will work closely with US Customs and intelligence organizations.

In addition to the 2 SERT teams, the RCMP will assign a member to MARLANT Headquarters.

The CF assets listed below have been tasked by TFCLANT through the appropriate operational level command headquarters to participate in "Helping Hand 2004-01". Air assets will be tasked via Air Tasking Orders or the "Rain Form" system.

a. 4 ADR, Royal Canadian Artillery UAV Detachment located at CFB Greenwood provides the LRE and a MCE to facilitate control of UAVs during transit to and from the AOO;

b. 5 UAVs from the 4 ADR Detachment CFB Greenwood. The LRE has 2 UAVs on 15 minute alert. Requests for additional assets will be made to 1 CAD through MARLANT;

c. HMCS Winnipeg will be deployed from Halifax with an RCMP SERT onboard. HMCS Winnipeg will be manned with a UAV MCE. There are no Sea King helicopters available for deployment. The Winnipeg will sail at 0600hrs;

d. CP-140 Aurora on 8 hour alert at 14 Wing CFB Greenwood has been brought up 3 hour alert. An additional CP-140 has been placed on 8 hour alert and will be brought up to 3 hour alert when the first Aurora is scrambled. All Auroras will be manned with a UAV MCE; and

e. HMCS Montreal is conducting a FISHPAT approximately 180nm southeast of Halifax. The Montreal has one UAV (Viper 01) that was launched from CFB Greenwood 12 hours ago, under its control. The Sea King Helicopter on board HMCS Montreal is unserviceable.

During the conduct of the mission, re-tasking direction will be issued by either written or verbal format from the designated command authority in order to change the mission or location of the UAV while it is airborne. Re-Tasking only occurs when the new mission is assigned a higher priority than the one undertaken in the initial tasking. Dynamic Re-Tasking is reserved for the UAV mission commander to immediately react to a changing situation as detected by the UAV during the course of either the initial tasking or re-tasking.

C.5.2 Manning

All MCEs have sufficient personnel to facilitate 24/7 manning for the duration of the mission.

C.5.3 Enemy Forces

This is a peacetime mission with peacetime Rules Of Engagement (ROEs) in effect; therefore, there are no actual "Enemy Forces" in the purest sense of the term. Vessels that are carrying contraband or are in violation of fishery regulations are the "enemy" in this scenario.

The RCMP have been advised that a SOI, the Motor Vessel (MV) Blade Runner, that both the RCMP and US authorities have been interested in for an extended period of time is presently 475nm south of Halifax heading north at 19 kts. The vessel is being shadowed by a US

Customs aircraft. It is believed that the MV Blade Runner is a mother ship carrying a large quantity of contraband to be off loaded to a smaller vessel for transportation ashore.

RCMP intelligence has confirmed that the fishing vessel "John D" currently tied along side in Yarmouth, NS is waiting to make contact with the MV Blade Runner for off loading of the contraband.

Although there are approximately 800 fishing vessels operating in the East Coast fishing zone, HMCS Montreal has not observed any infractions of fishery regulations.

C.5.4 Climate/Weather

This area frequently experiences extensive areas of fog and low cloud cover accompanied by precipitation at this time of year. These conditions would severely limit the use of EO and IR sensors.

The present weather is Ceiling and Visibility OK (CAVOK) throughout the AOO and is forecast to remain CAVOK for the duration of the mission.

C.5.5 Time and Space Constraints

The mission may be conducted at great distances from the home bases of the tasked assets; therefore, the ability to have theses assets available where and when they are needed is heavily dependant on timely and accurate intelligence information. Extended transit times are a major factor to be considered in mission planning.

Timely and accurate intelligence is also a major factor in determining the actual surveillance time required. Without high quality intelligence surveillance activities may have to be conducted for several days leading up to contact with the Targets Of Interest (TOI).

For this CD OP the positioning of assets is a major challenge.

C.6 Chronological Sequence of Mission Events

All times are Eastern Standard.

21 Mar 04

0200hr MARLANT headquarters are advised by Canadian North American Aerospace Defence Command (NORAD) Region that the US Customs aircraft currently shadowing the SOI has 1 hour of mission time remaining and the planned replacement aircraft is a ground abort with no replacement available. The SOI is 275nm southeast of Yarmouth NS and not 475nm south of Halifax as first reported. This means that the SOI is 10 hrs closer than was expected. See Figure 40.

0205hr MARLANT headquarters issues a scramble order to the 14 Wing Greenwood alert Aurora. A Second CP-140 is brought up to 3hr alert.

0206hr MARLANT headquarters issues a 0300hr ATO for one UAV from 4 ADR detachment. The UAV is ordered to an orbit point 100nm south of Yarmouth NS. A second UAV is brought up to 15min alert.

0207hr MARLANT headquarters orders HMCS Winnipeg to get underway.

0208hr MARLANT headquarters request authority from NDHQ to re-task HMCS Montreal from its current FISHPAT mission to the CD OP.

0210hr HMCS Montreal is directed to establish communications with the US Customs aircraft and standby for re-tasking to CD OP. The MCE Commander on HMCS Montreal is briefed on the mission by MARLANT. The HMCS Montreal is to utilize Viper 01 to shadow the SOI.

0215hr Communications are established between US Customs aircraft and HMCS Montreal.

0216hr The HMCS Montreal has a contact on its RMP 75nm south heading north. This contact is confirmed by US Customs Aircraft to be the SOI.

0230hr MARLANT headquarters has received authority from NDHQ Ottawa to re-task HMCS Montreal from its current FISHPAT mission to the CD OP.

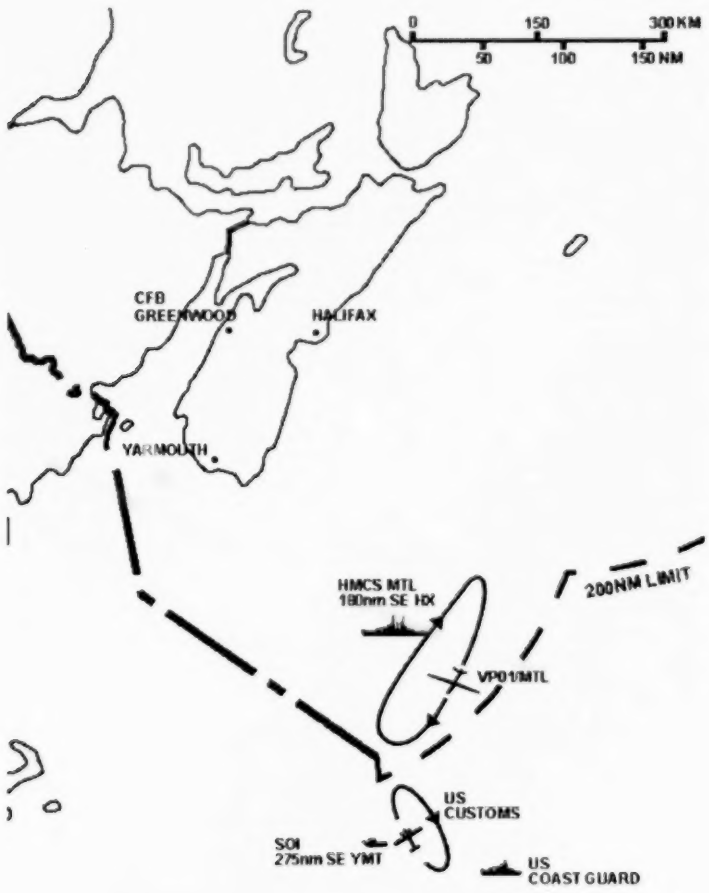

Figure 40: 0100 to 0200 Hrs

0231hr The MCE aboard the HMCS Montreal assumes responsibility for shadowing the SOI from the US Customs aircraft. The payload operator has taken the first SAR shot and is tracking the SOI by IR. The vehicle operator is vectoring Viper 01 at Flight Level (FL) 150 to optimize sensor performance.

0235hr The US customs aircraft has gone off station.

0236hr The SOI is presently 260nm southeast of Yarmouth still heading northwest at 19kts. See Figure 41.

0237hr UAV Viper 02 is airborne with its departure controlled by the LRE. The UAV has a pre-coordinated altitude reservation and after departure will be controlled by the 4 ADR MCE during transit to and from the AOO.

Figure 41: 0236 Hrs

0306hr Control of Viper 02 is passed from the LRE to the MCE. The MCE is receiving SIF/IFF codes from Viper 02 and therefore is able to assume control. Viper 02 will fly from programmed waypoint to waypoint from its present position to the AOO. The vehicle operator is monitoring the UAV's progress and providing flight safety. The payload operator is running the checklist for initiating the operation of the UAV's sensors and from this point on will monitor and manage their performance. The mission commander has established and will maintain radio communications with ATC and MARLANT Air Operations.

0330hr Viper 02 is presently 45nm south of CFB Greenwood cruising at FL 150 at 85 Knots Indicated Air Speed (KIAS). Viper 02 will be in position by 0500hrs.

0400hr HMCS Montreal and Viper 01 continue to shadow the SOI from a covert position, maintaining EO and IR tracking and reporting regularly on the SOI's progress and activities.

0430hr HMCS Winnipeg has put to sea with an RCMP SERT onboard. The ship will steam at 25kts and be in position before 1200hrs.

0435hr CP-140 Alpha 01 is airborne heading southeast at FL 250 and 205 KIAS and will be in an orbit point 100nm southeast of Yarmouth in approximately 90 minutes. Once established on station, Alpha 01 will assume control of both Viper 01 and Viper 02.

0440hr Alpha 01 MCE team conducts all equipment, data-link, and communications checks during the transit to the AOO.

0450hr Alpha 01 MCE mission commander contacts the 4 ADR MCE and receives an update on the status of Viper 02. 4 ADR reports that Viper 02 is approaching its orbit point 60nm south of Yarmouth and that all UAV sensors and systems are operational.

0455hr Alpha 01 MCE mission commander contacts the HMCS Montreal MCE and receives an update on the status of Viper 01. Montreal reports that Viper 01 has positive contact on the SOI 100nm from the ship and 200nm southeast of Yarmouth, all UAV systems and sensors are operational and that Viper 01 has approximately 10hrs of mission time remaining.

0500hr Viper 02 establishes an orbit approximately 60nm south of Yarmouth at FL 150. See Figure 42.

0555hr Alpha 01 reports to MARLANT that they are established in an orbit 100nm south of Yarmouth are ready to assume control of Viper 01 and Viper 02.

0556hr MARLANT delegates TACON of CD OP forces to Alpha 01 MCE.

0557hr Alpha 01 MCE contacts 4 ADR MCE and advises that they are ready to assume control of Viper 02 and passes 4 ADR a SIF/IFF code for Viper 02 to squawk for identification.

0558hr Alpha 01 has a positive SIF/IFF contact on their radar. They advise 4 ADR and take control of Viper 02.

0559hr Alpha 01 advises MARLANT that Viper 02 is under their control and that all sensors are operational. Alpha 01 passes a series of waypoints via data-link to Viper 02 that puts the UAV in a figure eight pattern. The payload operator takes

control of the UAV's sensors and keeps them pointed them southwest towards the position where the SOI is expected to appear.

0601hr Alpha 01 MCE contacts HMCS Montreal MCE and advises that they are ready to assume control of Viper 01 and passes Montreal a SIF/IFF code for Viper 01 to squawk for identification.

0602hr Alpha 01 has a positive SIF/IFF contact on Viper 01. They advise HMCS Montreal and take control of Viper 01.

0603hr Alpha 01 advises MARLANT that Viper 01 is under their control, all sensors are operational and that Viper 01 has EO and IR contact on the SOI. The SOI is currently 180nm southwest of Yarmouth

Alpha 01 vehicle operator transmits a series of waypoints to Viper 01 that establishes a pattern that allows the payload operator to keep the EO and IR sensors pointed at the SOI.

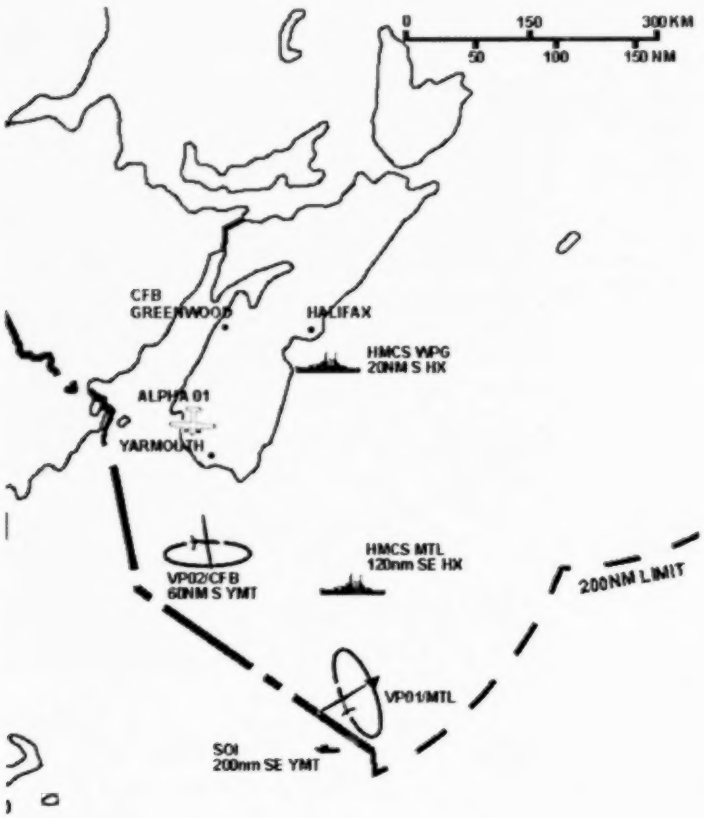

Figure 42: 0500 Hrs

0700hr HMCS Winnipeg is 45nm southeast of Halifax steaming at 25kts. MARLANT decides to re-task HMCS Montreal back to the FISHPAT mission and advises NDHQ. See Figure 43.

0701hr 4ADR LRE and MCE shift change takes place.

0702hr HMCS Montreal leaves Alpha 01's frequency and turns back to head east to continue FISHPAT.

0710hr HMCS Montreal MCE will complete all after action reports and debrief before going off watch.

0730hr Alpha 01 MCE continues to track the SOI with Viper 01 and search the area with Viper 02.

0735hr RCMP SERT 1 is in position in the vicinity of Yarmouth NS and have established radio contact via a Transportable Satellite Communications System (TSCS).

Figure 43: 0700 Hrs

0800hr The RCMP SERT reports that the John D is still in harbor but appears to be getting ready to leave.

0900hr The SOI is 140 nm southeast of Yarmouth being tracked by Viper 01. Alpha 01 mission commander decides to vector Viper 02 into position to take over tracking from Viper 01 and then move Viper 01 to Yarmouth to observe activity in that area before it has to Return To Base (RTB).

MARLANT headquarters issues a 1030hr ATO for one UAV from 4 ADR detachment. The UAV is ordered to replace Viper 01 at a point to be determined. A third UAV is brought up to 15min alert. See Figure 44

0915hr The payload operator correlates EO and IR information being received from Viper 02 with that received from Viper 01 and determines that Viper 02 has positive contact on the SOI. The SOI is now being tracked by Viper 02.

0916hr Alpha 01 vehicle operator transmits a number of way points to vector Viper 01 to a point 30nm outside of Yarmouth harbor.

Figure 44: 0900 Hrs

0917hr Alpha 01 provides MARLANT with a SITREP.

1000hr The vehicle operator established Viper 01 in a figure eight orbit 30nm south of Yarmouth at FL 130. The payload operator is monitoring activity at the harbor approaches.

HMCS Winnipeg is 100nm southwest of Halifax steaming southwest.

1030hr UAV Viper 03 is airborne with its departure controlled by the LRE. The UAV has a pre-coordinated altitude reservation and after departure will be controlled by the 4 ADR MCE during transit to and from the AOO.

1100hr MARLANT issues an ATO to 14 Wing Greenwood alert Aurora for 1400hrs

1145hr 4 ADR MCE advises Alpha 01 that they have Viper 03 going feet wet (transitioning from over land to over water) south of Yarmouth.

1146hr Alpha 01 advises that they are ready to assume control of Viper 03 and passes 4 ADR a SIF/IFF code for Viper 03 to squawk for identification.

1147hr Alpha 01 has a positive SIF/IFF contact on their radar. They advise 4 ADR and take control of Viper 03.

Alpha 01 requests 4ADR MCE to take control of Viper 01 for RTB Greenwood.

4ADR requests a specific SIF/IFF squawk for Viper 01.

NOTE: At this time Alpha 01 MCE has 3 UAVs under their control.

1148hr 4ADR advises that they have positive SIF/IFF and assumes control of Viper 01.

1149hr Alpha 01 advises MARLANT that Viper 03 is under their control, all sensors are operational and Viper 01 has been handed off to 4ADR for RTB Greenwood.

1150hr Alpha 01 passes a series of waypoints via data-link to Viper 03 that puts the UAV in figure eight pattern at FL 130. The payload operator takes control of the UAV's sensors and keeps them pointed toward the entrance to Yarmouth harbor.

1200hr Viper 02 under the control of Alpha 01 is maintaining EO and IR contact on the SOI 90nm southeast of Yarmouth heading northwest. The payload operator is taking SAR shots regularly.

1200hr HMCS Winnipeg reports that they are 45nm east of Yarmouth and will be on station within the hour.

Viper 03 under the control of Alpha 01 continues to monitor the approaches to Yarmouth harbor. See Figure 45.

1300hr The RCMP SERT team reports that the John D is underway.

1330hr 4 ADR MCE hands Viper 01 to the LRE for recovery.

1335hr Viper 03 has an EO contact leaving Yarmouth harbor. The payload operator takes a series of SAR shots.

1345hr EO images confirm that the contact leaving Yarmouth is the John D. The contact is heading southwest. The vehicle operator manually vectors Viper 03 to a different orbit in order to maintain tracking on the John D.

Alpha 01 mission commander passes a SITREP to MARLANT.

1350hr HMCS Winnipeg reports to be on station at a point off the southern tip of Nova Scotia beyond line of sight of both the SOI and John D.

1351hr CP-140, Alpha 02 is airborne heading Southeast at FL 230 at 225 KIAS and will be in position to relieve Alpha 01 at 1510hrs.

1355hr Alpha 02 MCE team conducts all equipment, data-link, and communications checks during the transit to the AOO. Alpha 02 MCE mission commander contacts Alpha 01 and receives mission updates. Alpha 01 reports that they have Viper 02 and Viper 03 under their control and are currently tracking both the SOI and the fishing vessel John D.

Alpha 02 establishes radio contact with RCMP SERT team in Yarmouth and with HMCS Winnipeg.

Figure 45: 1200 Hrs

1400hr Alpha 01 mission commander decides to hand off Viper 02 to HMCS Winnipeg for continued tracking of the SOI.

1401hr Alpha 01 MCE contacts HMCS Winnipeg MCE and requests that Winnipeg assumes control of Viper 02.

HMCS Winnipeg confirms that they are ready to assume control of Viper 02 and requests that the UAV change SIF/IFF squawk for identification.

1402hr HMCS Winnipeg has a positive SIF/IFF contact on their radar. They advise Alpha 01 and take control of Viper 02.

1403hr HMCS Winnipeg advises MARLANT that Viper 02 is under their control, all sensors are operational and that Viper 02 has EO and IR contact on the SOI. The SOI is currently 75nm southeast of Yarmouth.

1430hr Viper 02 under the control of HMCS Winnipeg is maintaining EO and IR contact on the SOI 70nm southeast of Yarmouth heading northwest. The payload operator is taking SAR shots regularly. Viper 02 information is being transmitted to Alpha 01.

Viper 03 under the control of Alpha 01 is maintaining EO and IR contact on the John D 05nm southeast of Yarmouth heading southeast. The payload operator is taking SAR shots regularly. Viper 03 information is being transmitted to HMCS Winnipeg.

At the present rate of closure between the SOI and the John D the rendezvous should take place at about 1730hrs outside of Yarmouth.

1500hr 4 ADR LRE and MCE shift change takes place.

1505hr Alpha 02 advises MARLANT that they are on station and ready to assume TACON from Alpha 01.

MARLANT directs Alpha 02 to relieve Alpha 01.

1506hr Alpha 02 MCE requests that Viper 02 and Viper 03 change SIF/IFF squawks for identification purposes.

1507hr Both UAVs squawk the requested codes.

1508hr Alpha 02 has positive contact on both UAVs.

1509hr Alpha 02 assumes control of Viper 03 and is receiving data from both Viper 02 and Viper 03.

1510hr Alpha 02 advises MARLANT that they have taken TACON from Alpha 01 and have assumed control of Viper 03.

1511hr Alpha 01 advises MARLANT that they are off station, RTB Greenwood. The MCE will complete all after action reports and prepare for debrief during the transit to Greenwood.

1530hr The SOI is being tracked 65nm south Yarmouth tracking northwest.

The John D. is being tracked 15nm south of Yarmouth but has turned back north. See Figure 46.

1558hr Alpha 02 reports that the John D is circling at a point 07nm south of Yarmouth.

1630hr In a SITREP to MARLANT, Alpha 02 reports that Viper 03 is tracking the John D which is still circling south of Yarmouth and that Viper 02 under the control of

HMCS Winnipeg is now 45nm south of Yarmouth and 38nm south of the John D. heading northwest.

1745hr The John D is now heading south and appears to be on a track directly to the SOI which is 9nm south. This activity is being observed by the EO and IR sensors aboard Viper 02 and Viper 03. Both UAVs are taking numerous SAR shots.

Figure 46: 1530 Hrs

1800hr The John D is along side of the SOI and both ships are dead in the water at a point 8nm south of Yarmouth drifting north. See Figure 47.

1810hr Both UAVs observe cargo being off loaded from the SOI to the John D.

1840hr The off-loading has been completed. The John D turns north and heads to Yarmouth. The SOI turns south.

All activity is being observed by the EO and IR sensors aboard Viper 02 and Viper 03. Both UAVs are taking numerous SAR shots. All data is being down

linked to MARLANT and the mission commanders onboard HMCS Winnipeg and Alpha 02 are providing MARLANT with voice updates.

The RCMP SERT has been monitoring all radio traffic and is aware that the John D is their target and it is heading to Yarmouth.

1841hr Alpha 02 is providing the RCMP SERT with constant voice updates.

Figure 47: 1800 Hrs

1842hr Viper 03 under the control of Alpha 02 continues to track the John D and Viper 02 under the control of HMCS Winnipeg continues to track the SOI.

1843hr SOI stops 10nm south of Yarmouth and puts a small high speed craft over the side.

1844hr The high speed craft heads northeast.

1845hr Alpha 02 mission commander decides to re-task Viper 03 from the John D to tracking the high speed craft.

1846hr Alpha 02 is sending frequent SITREPs to MARLANT.

1905hr The John D enters Yarmouth harbor.

1910hr The high speed craft is approaching Wedgeport habour under the surveillance of Viper 03.

1911hr RCMP dispatches 4 SERT members from Yarmouth to Wedgeport.

1915hr The HMCS Winnipeg gives up her covert position to intercept the SOI.

1940hr The SOI has stopped after being hailed by the HMCS Winnipeg and the RCMP SERT is preparing to board.

1945hr The John D is coming along side in Yarmouth and the RCMP SERT are preparing to move into position.

Viper 02 and Viper 03 will loiter and continue to observe and record all activities with data being down linked to MARLANT.

1950hr The high speed craft enters Wedgeport habour under the surveillance of Viper 03.

2000hr HMCS Winnipeg reports that the RCMP SERT is onboard the Blade Runner. The SERT will remain onboard and the HMCS Winnipeg will escort the ship to Halifax. The ships are heading northeast to Halifax at 17kts.

2015hr MARLANT directs HMCS Winnipeg to terminate UAV surveillance of the SOI.

2016hr Alpha 02 mission commander requests that HMCS Winnipeg maintain control of Viper 02 and vector the UAV north from its present position, 35nm southeast of Yarmouth and standby for RTB instructions.

2017hr Alpha 02 receives clearance from 4 ADR to hand Viper 02 directly to 4 ADR MCE for immediate recovery.

2018hr Alpha 02 mission commander directs the HMCS Winnipeg to hand Viper 02 off to 4 ADR MCE.

2019hr HMCS Winnipeg contacts 4 ADR to initiate the handover. They are directed to vector the UAV north at FL 150 squawking a specific SIF/IFF code for identification.

2020hr 4 ADR has positive radar contact on Viper 02 and assumes control of the UAV.

2021hr 4 ADR advises ATC and 14 Wing operations that they have Viper 02 under their control for immediate RTB Greenwood.

2030hr Alpha 02 continues to vector Viper 03 maintaining EO and IR surveillance and taking numerous SAR shots.

2100hr The Yarmouth and Wedgeport end games are complete. MARLANT directs Alpha 02 to terminate Helping Hand 2004-01.

2101hr Alpha 02 contacts 4ADR to initiate the handover of Viper 03 which is presently 3 nm south of Yarmouth. They are directed to vector the UAV north at FL 150 squawking a specific SIF/IFF code for identification.

2102hr 4 ADR has positive radar contact on Viper 03 and assumes control of the UAV.

2110hr Alpha 02 turns north heading to Greenwood for recovery. The MCE team will complete as much of the required post mission reports and returns as possible during the transit to greenwood.

2155hr 4 ADR LRE reports Viper 02 down at 2139hr.

2245hr 4 ADR LRE reports Viper 03 down at 2244hr.

2250hr 14 Wing Ops reports Alpha 02 down at 2249hrs.

2300hr MARLANT stands down and post mission activities commence.

C.7 Timeline of Major Scenario Events for IAI Testing

As previously mentioned, the intended use of the mission scenario is as a baseline facility for IAI experimentation. The UAV structure provides the testbed for which the impact of IAI constructs upon UAV operations can be evaluated. To assist this effort, Figure 48 illustrates the mission scenario timeline annotated with major events. The timeline has also been divided into seven 'chunks' whereby each chunk is deemed conducive for IAI experimentation. Selection of the chunks was based on identifying periods within the scenario that may exhibit excessive operator workload due to factors such as simultaneous receipt of sensor data from multiple UAVs, dynamic re-tasking of UAVs, transfer of UAV control between agencies, and/or concurrent control of multiple UAVs. The seven chunks considered for experimentation are the following:

a. **0210 – 0231 hrs:** The MCE onboard the HMCS Montreal has been ordered to re-task Viper 01 from its current mission (FISHPAT) to the CD OP. In turn, Viper 01 must be vectored to begin and maintain tracking of the SOI.

b. **0237 – 0603 hrs:** This series of events exercises multiple transfers of UAV control between land based, ship board, and airborne MCEs. The end result is Alpha 01 MCE assuming simultaneous control of two UAVs (Viper 01 and Viper 02).

c. **0730 – 1000 hrs:** Alpha 01 controls two UAVs and monitors their sensor data. In addition, Alpha 01 dynamically re-tasks the missions of these UAVs.

d. **1030 – 1148 hrs:** Alpha 01 MCE has three UAVs under simultaneous control for a brief period of time.

e. **1300 – 1510 hrs:** Multiple targets are being tracked while control of UAVs and TACON is transferred between Alpha 01 and Alpha 02.

f. **1800 – 2015 hrs:** As the tempo of activity increases, the level of UAV sensor operations and frequency of reporting increases respectively.

g. **2015 – 2245 hrs:** Mission has been completed and control of the UAVs is transferred from the operational MCEs to the LRE.

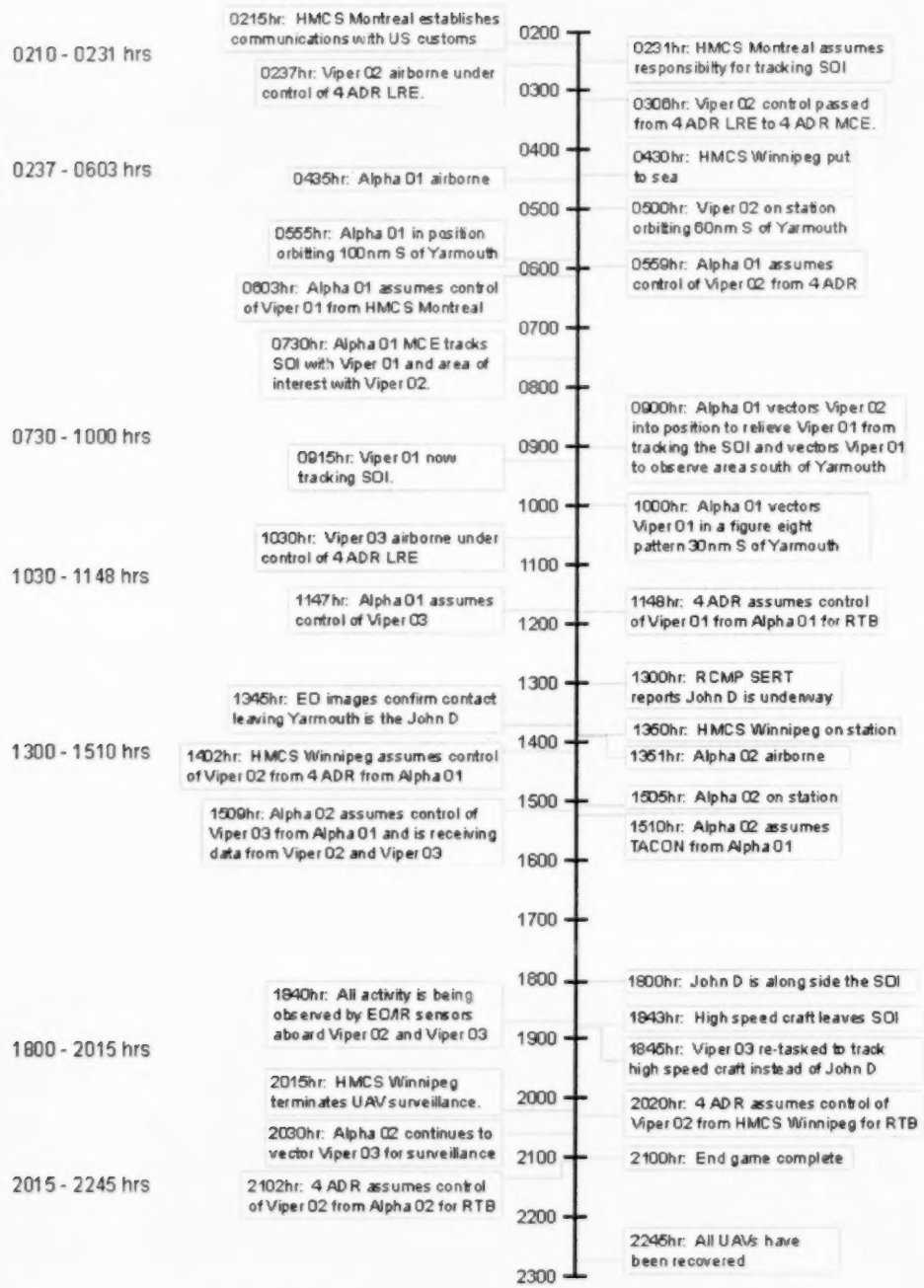
0210 - 0231 hrs
0215hr: HMCS Montreal establishes communications with US customs
0237hr: Viper 02 airborne under control of 4 ADR LRE.
0237 - 0603 hrs
0435hr: Alpha 01 airborne
0555hr: Alpha 01 in position orbitting 100nm S of Yarmouth
0603hr: Alpha 01 assumes control of Viper 01 from HMCS Montreal
0730hr: Alpha 01 MCE tracks SOI with Viper 01 and area of interest with Viper 02.
0730 - 1000 hrs
0915hr: Viper 01 now tracking SOI.
1030hr: Viper 03 airborne under control of 4 ADR LRE
1030 - 1148 hrs
1147hr: Alpha 01 assumes control of Viper 03
1345hr: EO images confirm contact leaving Yarmouth is the John D
1300 - 1510 hrs
1402hr: HMCS Winnipeg assumes control of Viper 02 from 4 ADR from Alpha 01
1509hr: Alpha 02 assumes control of Viper 03 from Alpha 01 and is receiving data from Viper 02 and Viper 03
1840hr: All activity is being observed by EO/IR sensors aboard Viper 02 and Viper 03
1800 - 2015 hrs
2015hr: HMCS Winnipeg terminates UAV surveillance.
2030hr: Alpha 02 continues to vector Viper 03 for surveillance
2015 - 2245 hrs
2102hr: 4 ADR assumes control of Viper 02 from Alpha 02 for RTB
0200
0300
0400
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
0231hr: HMCS Montreal assumes responsibilty for tracking SOI
0306hr: Viper 02 control passed from 4 ADR LRE to 4 ADR MCE.
0430hr: HMCS Winnipeg put to sea
0500hr: Viper 02 on station orbitting 60nm S of Yarmouth
0559hr: Alpha 01 assumes control of Viper 02 from 4 ADR
0900hr: Alpha 01 vectors Viper 02 into position to relieve Viper 01 from tracking the SOI and vectors Viper 01 to observe area south of Yarmouth
1000hr: Alpha 01 vectors Viper 01 in a figure eight pattern 30nm S of Yarmouth
1148hr: 4 ADR assumes control of Viper 01 from Alpha 01 for RTB
1300hr: RCMP SERT reports John D is underway
1360hr: HMCS Winnipeg on station
1351hr: Alpha 02 airborne
1505hr: Alpha 02 on station
1510hr: Alpha 02 assumes TACON from Alpha 01
1800hr: John D is alongside the SOI
1843hr: High speed craft leaves SOI
1845hr: Viper 03 re-tasked to track high speed craft instead of John D
2020hr: 4 ADR assumes control of Viper 02 from HMCS Winnipeg for RTB
2100hr: End game complete
2245hr: All UAVs have been recovered

Figure 48: Timeline of Major Scenario Events

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14. ABSTRACT

(U) This document presents a Mission and Scenario Analysis which captures the nature of the UAV/UCAV domain within Canada. The information contained within this report will facilitate the continued development of the knowledge-base associated with two emerging technology threads: UAV/UCAV devices and Intelligent/Adaptive Interfaces (IAIs). Two scenarios were produced as a result of this exercise with the intent to provide a baseline facility for the development of an experimental landscape for the evaluation of IAI constructs. The UAV operational context was utilized primarily because of its intense, yet bounded, command and control architecture. The original scenario was developed for DRDC to provide a framework to illustrate the elements described in the mission analysis and to identify the unique mission-critical operational activities performed by the UAV MCE team on an airborne platform. Additional requirements identified by CFEC warranted the creation of a next generation mission scenario that mimics elements of the upcoming Atlantic Littoral ISR Experiment (ALIX) as well as portray potential Canadian Forces UAV capabilities. Both scenarios are based on the same type of mission (counter drug operations) composed from a similar sequence of events. The primary deviation is the employment of a family of UAVs (MALE, Tactical, and Mini UAVs) in the next generation scenario as opposed to solely a MALE UAV in the original scenario.

(U) Le présent document renferme l'analyse d'une mission et d'un scénario cernant la nature du domaine des UAV/UCAV à l'intérieur du Canada. Les renseignements qui font partie de ce rapport faciliteront le développement continu de la base des connaissances associées à deux sujets relatifs à la technologie émergente : les UAV/UCAV et les interfaces intelligentes/adaptatives (IIA). À la suite de cet exercice, on a établi deux scénarios avec l'intention de fournir une installation de base afin de développer un contexte expérimental pour l'évaluation de concepts d'IIA. Le contexte opérationnel des UAV a été utilisé principalement à cause de son architecture de commande et de contrôle intense mais limitée. Le scénario d'origine a été élaboré pour RDDC, afin de fournir un cadre pour illustrer les éléments décrits dans l'analyse de la mission et identifier les uniques activités opérationnelles essentielles à la mission auxquelles s'adonne l'équipe MCE des UAV sur une plate-forme aéroportée. Les exigences additionnelles identifiées par le CEFC justifiaient la création d'un scénario de mission de la prochaine génération simulant les éléments de la prochaine expérience de RSR sur le littoral atlantique (ALIX) et décrivant les capacités susceptibles de posséder les UAV des Forces canadiennes. Ces deux scénarios sont basés sur le même type de mission (opérations de lutte antidrogue) et constitués d'une séquence similaire d'événements. La principale différence tient à l'utilisation d'une famille d'UAV (MALE, tactiques et miniaturisés) pour le scénario de la prochaine génération, au lieu d'un UAV MALE seulement, comme dans le scénario d'origine.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) UAV; UCAV; multiple UAV; multiple UCAV; operational scenario; UAV control; UCAV control, airbone platform